# Research on Scheduling Optimization and Simulation of Marine Crankshaft Workshop Based on Algorithm

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## Abstract

With the rapid development of the shipping industry, the scale of the industry continues to expand, the output of shipbuilding is growing rapidly, and the comprehensive strength of enterprises is also increasing, but they are also facing certain challenges, such as the low efficiency of enterprises, overcapacity and so on. Shipbuilding enterprises need to transform and upgrade themselves, constantly update and replace, in order to maintain the healthy and stable development of the shipbuilding industry, enhancing the management and production level of enterprises is very meaningful for shipbuilding enterprises. The crankshaft processing and production are indispensable in ship manufacturing. The optimization of crankshaft processing and production links can save costs, improve efficiency and improve management for crankshaft manufacturing enterprises. This paper takes Z crankshaft company as an example to optimize and analyze the logistics part of the crankshaft processing workshop. This paper mainly studies the production scheduling problem of Z crankshaft company, establishes a mathematical model, uses genetic algorithm, and uses MATLAB and simulation technology to study, in order to reduce enterprise costs, improve production capacity and improve management level.

## Keywords

Crankshaft workshop,algorithm,simulation,optimization,flexsim,matlab.

## 1. Introduction

### 1.1 Background of topic selection and research significance

As China pays more and more attention to the development of manufacturing industry, advanced manufacturing industry is becoming our country's strategic industry. With the hindrance of economic globalization, we must master the core technology. Although our country's manufacturing industry has developed rapidly, there is still a big gap compared with foreign countries. Especially the development of high-end manufacturing industry is lagging behind, and it started relatively late in recent years. The development direction of manufacturing industry tends to the direction of intelligent manufacturing. The production management in enterprises is relatively backward and informationized. It can not track and analyze the market and production status and product status well. Production scheduling, as an important part of enterprise production and management, has not been paid enough attention. As far as the current situation is concerned, there are the following problems in enterprise production logistics:

(1) In job shop scheduling, it is very difficult to achieve intelligent scheduling because it relies entirely on personal experience to arrange the processing of parts. Due to the scattered distribution of equipment in many months, it is easy to cause unbalanced equipment load and increase the idle time of equipment. At the same time, human factors have a greater impact on production, which also increases the randomness of production.

(2) Because there is no basic production management information system, the production information is scattered and disordered. Usually, a lot of information is very important to command the next production cycle, the next day, or even the next hour. In manual processing mode, it is necessary to rely on scheduling to query paper-based data one by one. On-site inquiry or testing, manual recording and statistical summary, not only the workload is large, but also the speed is slow, it is difficult to improve work efficiency, and it is difficult to achieve the processing workshop and other jobs. The information sharing of energy departments makes it difficult for decision-making departments to issue correct production instructions in time.

(3) There is no quantitative analysis on the processing time and equipment utilization of parts, which results in insufficient basis for making production plans and making production scheduling decisions.

(4) Many production-related data are not recorded due to workload constraints or incomplete and non-standard records, so it is difficult to trace some responsible accidents caused by management errors. Even the recorded data will inevitably make mistakes in the statistical summary, which are difficult to meet the requirements of modern enterprise management to speak with numbers and achieve scientific management. Dispatching work lacks foresight and prevention. In the production process, we often encounter some unexpected problems, which require dispatchers to adjust their work plans in time. At the same time, dispatching work should focus on prevention, and we must avoid passive grasping of missing parts and plugging loopholes, which are difficult to achieve without the help of computers and by manual management alone.

Processing large crankshaft is the master of our country's high-end industry. It needs high-end machine tools, complete management methods and perfect cooperation among production factors to produce large-scale crankshaft of high quality. From the above situation, we can see that reasonable production scheduling of enterprises plays an indelible role in improving productivity and production efficiency and ensuring production quality. Enterprises should attach importance to life. The economic benefits brought by the optimization of production dispatch regard the continuous optimization and improvement of production dispatch as a part of enterprise operation and production.

The significance of this study is as follows:

(1) To standardize and specify the production instructions of dispatching, so as to make the dispatching work planned, reasonable and predictable, and to ensure the close connection of all links of production dispatching.

(2) Optimizing production scheduling function can provide important basis for production decision-making. At the same time, the system realizes computer management in production scheduling and management, which improves the scientificity and effectiveness of management. By organizing the production process reasonably, the inventory of finished products, semi-finished products and blanks can be reduced, and waste can be eliminated.

(3) A great deal of statistical work and information transmission work are completed by computer, which can save part of the management cost, input workload and improve the speed and accuracy of information processing.

(4) Using Flexsim and other simulation software, one or two optimal production scheduling algorithms can be given, which are analyzed by combining the modeling before and after simulation.

### 1.2 Research status at home and abroad

Many domestic enterprises are very vague about the concept of workshop production scheduling. They do not think that optimizing production scheduling has a great effect on improving economic efficiency. Therefore, there are various problems in the workshop of many enterprises in China. To solve the problem of production scheduling optimization in enterprise workshop, some domestic experts and scholars have done a lot of in-depth research, and put forward many practical solutions.

Literature [1] describes a scheduling strategy considering learning and forgetting effects in group production. Document [2] optimizes production scheduling in flow shop considering periodic maintenance of equipment. Literature [3] analyzed the layout characteristics of existing manufacturing systems, and prospected the future layout mode of workshop equipment. Literature [4] Integrated research on production scheduling and equipment maintenance based on multi-objective optimization. Literature [5] A new MILP model for multi-product batch production scheduling is studied and constructed. Document [6] presents an object-oriented unified model framework for FMS, and studies the selection of FMS machine tools under this framework.

## 2. Current situation analysis of workshop production scheduling in crankshaft company

### 2.1 Analysis on production scheduling problem of crankshaft company

Founded in April 2002, Z Company is one of the major marine crankshaft manufacturers in China. The company invested 780 million yuan in the first and second phases, covering an area of 100,000 square meters, with an annual production capacity of 240 marine crankshafts. In order to better understand the company's situation, the following figure shows a common product of Z company's marine crankshaft, 7G80ME crankshaft.

Figure 2-1 Part of 7G80ME Marine Crankshaft of Z Company

According to the above theoretical analysis, combined with the actual situation of the company, it is concluded that the design of 7G80ME production line does not consider the problem of automated logistics and automatic feeding and unloading at first. Secondly, the equipment is designed according to the manual small unit operation, and the logistics line is placed on the side of the production line, which leads to the long manual feeding and unloading path and the long assistant time. Moreover, without introducing the idea of scientific management, the balance rate of production line is analyzed and the bottleneck process is found out, and the time of bottleneck process is compressed. Therefore, the suggestions for the analysis of production scheduling problem of Z Marine Crankshaft Company in this section are as follows:

(1) Draw process flow chart and equipment layout.

(2) Measure the processing rhythm and auxiliary loading and unloading time of each equipment in the production line by stopwatch, draw TT-CT chart, and find out the bottleneck process.

(3) It is helpful for ECRS analysis to analyze whether some processes in the process can be merged, simplified or cancelled, and optimize the process flow.

(4) Use SW1H method, ECRS analysis method and action analysis method to find out the bottleneck process problems, find out the reasons and optimize the solution.

(5) Design automated logistics, reduce manual handling labor intensity and reduce the number of operators to achieve the goal of saving people, improving efficiency and improving management level.

(6) Concentrate the manual assistant process to reduce the walking distance of personnel;

(7) Optimize and improve the process and process flow, establish standard process system, and establish the standardization of the whole process of man, machine, material, method, ring and measurement.

(8) Realize the automation of key processing equipment, realize "man-machine separation", liberate operators from the process of monitoring equipment, eliminate the dependence of equipment on personnel through research, including improving the CPK capability of equipment to eliminate 100% measurement, solve the automatic positioning of equipment, automatic top-up, automatic chip blowing, increase tool monitoring and detection, abnormal alarm, abnormal situation automatic shutdown. And so on. Solve the awkward situation of "labor-saving and unconscious" of automatic line.

(9) Automation of production line logistics. That is to realize the automatic feeding and unloading of single machine, multi-machine linkage, increase automatic raceway for material transmission when necessary, cancel manual feeding and unloading, and manual working procedure turnover. By studying the practical application of robots, manipulators and self-animal raceway in feeding and unloading and working procedure turnover, the normal production process of the production line is basically unmanned, and only a small number of operators are set up for production. Line to carry out the necessary inspection, exception handling and other work. In this way, the "automation" of production process can be realized.

(10) For the use of robots and manipulators, comprehensive considerations are made from the following aspects: the space position of equipment loading and unloading, the arrangement of equipment on the whole line, the convenience of changing production, the handling and buffering of abnormal factors in production line such as tool changing adjustment, the respective use efficiency of robots and manipulators, the number of operable equipment, the one-time cost input and operation cost.

(11) Realize lean production management. That is to say, after the change of production mode, the corresponding management mode should be studied and implemented. Including the statistics and promotion of OEE equipment, the establishment of alarm mechanism for abnormal production line (the use of the light system), the establishment of problem-solving mechanism for suspending production line to solve problems, the establishment of timed wage system, shift design and working time operation mechanism, the establishment of mandatory tool replacement mechanism, the establishment of material distribution mechanism of production line, the establishment of single-piece flow production mode, etc. Change the production management mode and implement the standardized lean management mode of Z Company.

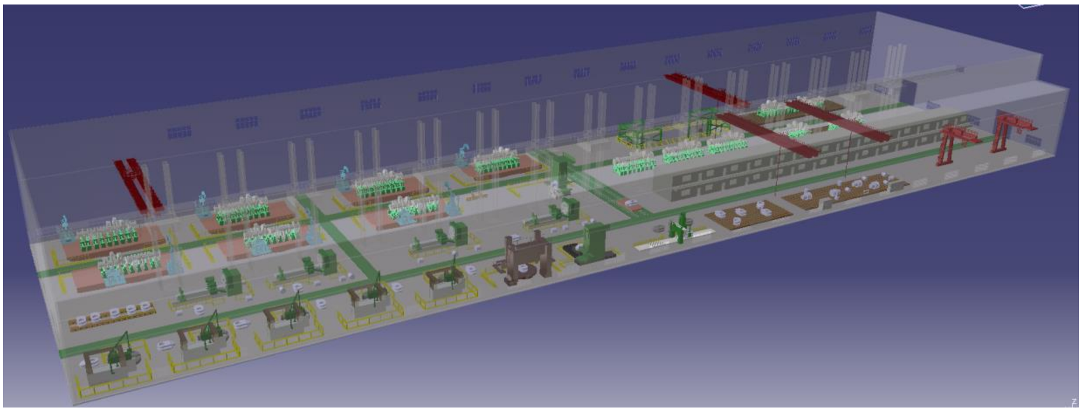

Figure 2-2 Three-dimensional model of factory building

### 2.2 Layout of production workshop in Z crankshaft company

The workshop of Z Crankshaft Company mainly includes five CNC crankshaft lathe areas, one CNC cyclone cutting crankshaft lathe area, one crankshaft blank area, three parts processing areas, one crankshaft red sleeve pit, one crankshaft splicing site, one finished product stacking area, one marking platform, one finished crankshaft area, one workpiece turning platform, one single crankshaft sleeve area, and one crankshaft grinding room.

The layout of three-dimensional model of workshop is established in the environment of CATIA software of Dassault as shown in Figure 2-2.

### 2.3 Constructing the optimum model of workshop production scheduling in Z crankshaft company

By collecting data, the optimization model of workshop production scheduling of Z crankshaft company is established as shown in the following figure. In this model, there are seven main processes: crank finishing process, crankshaft single set process, crankshaft red set process, output end finishing process, spindle neck finishing process, free end finishing process, crankshaft crankshaft process. Among them, crank finish processing technology, output finish processing technology, spindle neck finish processing technology and free end finish processing technology are independent and can work separately, but there is a situation of common equipment. Single process and red set process need finishing before they can start. The processing object of single process is finished crank, finished main diameter shaft, finished output, and the addition of red set process. The object is the combination of the free end and the single set.

In this production scheduling model, due to the wide variety and quantity of blanks to be processed and the limited equipment available for processing, when and on which equipment each product is produced has always been a difficult problem for enterprises. At present, there is no systematic research. The formulation of production scheduling mainly depends on experience. In this case, it can not effectively reduce costs and improve efficiency. The objective of this study is to determine when and where each blank is produced, and determine the path of blank processing, so as to achieve the shortest total construction period and the lowest cost.

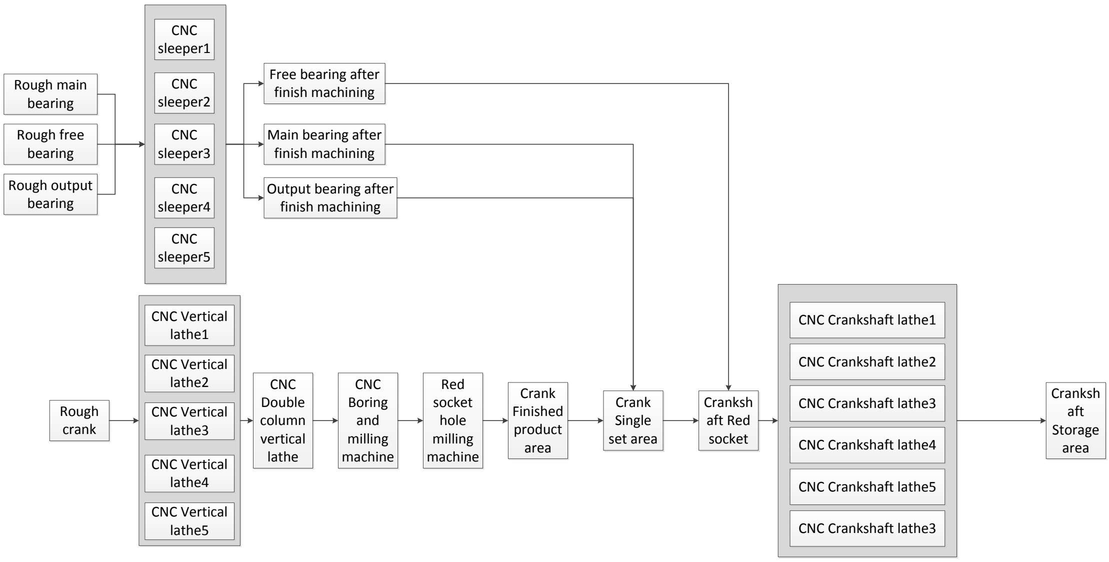


Figure 2-3 Schematic diagram of production scheduling optimization model

The objective function of the crankshaft workshop production system can be expressed as:

$$\min\max\left(\sum_{i=1}^{I}\sum_{j=1}^{J}(x_{ijm}+Tx_{ijm}),\sum_{i=1}^{I}\sum_{j=1}^{J}(y_{ijm}+Ty_{ijm}),\sum_{i=1}^{I}\sum_{j=1}^{J}(z_{ijm}+Tz_{ijm}),\sum_{i=1}^{I}\sum_{j=1}^{J}(q_{ijm}+Tq_{ijm})\right) \quad (3.1)$$

*Subject to*:

$$x_{i,j,m} \ge x_{i,j-1,m}+Tx_{i,j-1,m} \quad (3.2)$$

$$y_{i,j,m} \ge y_{i,j-1,m}+Ty_{i,j-1,m} \quad (3.3)$$

$$z_{i,j,m} \ge z_{i,j-1,m}+Tz_{i,j-1,m} \quad (3.4)$$

$$q_{i,j,m} \geq q_{i,j-1,m} + Tq_{i,j-1,m} \tag{3.5}$$

$$x_{i,j,m} \geq x_{i^{'},j^{'},m} + Tx_{i^{'},j^{'},m} + M(1-\sigma_{iji^{'}j^{'}}^{tm}) \tag{3.6}$$

$$y_{i,j,m} \geq y_{i^{'},j^{'},m} + Ty_{i^{'},j^{'},m} + M(1-\sigma_{iji^{'}j^{'}}^{tm}) \tag{3.7}$$

$$z_{i,j,m} \geq z_{i^{'},j^{'},m} + Tz_{i^{'},j^{'},m} + M(1-\sigma_{iji^{'}j^{'}}^{tm}) \tag{3.8}$$

$$q_{i,j,m} \geq q_{i^{'},j^{'},m} + Tq_{i^{'},j^{'},m} + M(1-\sigma_{iji^{'}j^{'}}^{tm}) \tag{3.9}$$

$$x_{i^{'},j^{'},m} \geq z_{i,j,m} + Tz_{i,j,m} + M(\sigma_{iji^{'}j^{'}}^{tm}) \tag{3.10}$$

$$y_{i^{'},j^{'},m} \geq y_{i,j,m} + Ty_{i,j,m} + M(\sigma_{iji^{'}j^{'}}^{tm}) \tag{3.11}$$

$$z_{i^{'},j^{'},m} \geq z_{i,j,m} + Tz_{i,j,m} + M(\sigma_{iji^{'}j^{'}}^{tm}) \tag{3.12}$$

$$q_{i^{'},j^{'},m} \geq q_{i,j,m} + Tq_{i,j,m} + M(\sigma_{iji^{'}j^{'}}^{tm}) \tag{3.13}$$

$$x_{ijm} = \frac{x_{ijm}}{signD} \quad \text{(m belongs to single set and red set equipment)} \tag{3.14}$$

The objective function (3.1) indicates that the maximum processing time of all blanks is the shortest according to the process operation.

Constraint (3.2) - (3.5) means that the start time of each process should be greater than the end time of the previous process, which is the constraint of processing sequence.

Constraint (3.6) - (3.13) means that each equipment can only process one workpiece at the same time, which is equipment constraint.

Constraint (3.14) means that only when the process before the single set and the red set is completed and sufficient workpieces are available, can the process be operated.

## 3. Solution of scheduling problem based on fuzzy algorithms and genetic algorithms

Genetic algorithm is very suitable for solving production scheduling problem, because unlike heuristic method, genetic algorithm operates on a set of solutions rather than a single solution. In production scheduling, this solution generally includes many answers, which may have different and sometimes conflicting objectives. The following is part of the code:

```
nProblems = 10; nRuns = 4;
FVAL = NaN(nProblems,nRuns);
for  p = 1:nProblems

   [lb, ub,FITNESSFCN] = ProblemDetails(p);

   Nvars = length(lb);  Sol = NaN(nRuns,Nvars);

   options = gaoptimset('PopulationSize', 100,'Generations',500, 'TolCon', 0, 'StallGen', 500);

   for r = 1:nRuns
      rng(r, 'twister');
      [Sol(r,:), FVAL(p,r)] = ga(FITNESSFCN,Nvars,[],[],[],[],lb,ub,[],1:Nvars,options);
   end
```

```
for i = 1 : N
    % Number of individuals that dominate this individual
    individual(i).n = 0;
    % Individuals which this individual dominate
    individual(i).p = [];
    for j = 1 : N
        dom_less = 0;
        dom_equal = 0;
        dom_more = 0;
        for k = 1 : M
            if (x(i,V + k) < x(j,V + k))
                dom_less = dom_less + 1;
            elseif (x(i,V + k) == x(j,V + k))
                dom_equal = dom_equal + 1;
            else
                dom_more = dom_more + 1;
            end
        end
        if dom_less == 0 && dom_equal ~= M
            individual(i).n = individual(i).n + 1;
        elseif dom_more == 0 && dom_equal ~= M
            individual(i).p = [individual(i).p j];
        end
    end
    if individual(i).n == 0
        x(i,M + V + 1) = 1;
        F(front).f = [F(front).f i];
    end
end
```

In this paper, we propose a two-stage grammar-based genetic algorithm, which is used to solve the workshop scheduling problem in an educational environment that respects partially the preferences of participants. The solution considers the limitation of workshop capacity and allows different scheduling types. We solve this problem by defining a grammar that defines a language to express constraints on seminars and participants. A word in this formal language denotes a solution that is always feasible according to the definition of the language. For each feasible scheduling, fitness is the result of optimizing the group social welfare function, which is defined as the sum of individual utility functions and expressed by partial preference. This optimization is achieved by a sequential genetic algorithm, which assigns each participant's personal schedule to them. The simulation results are as follows in the 3 pictures below, figure 1, figure 2,figure 3:

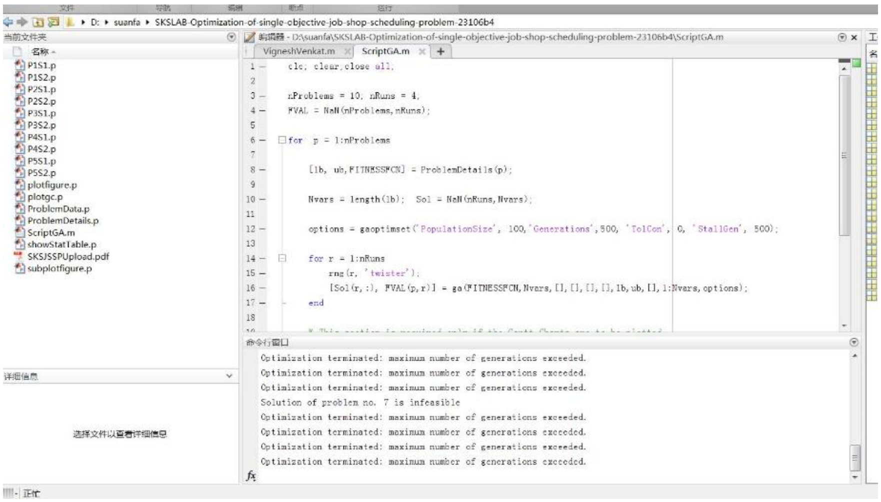

Figure 1

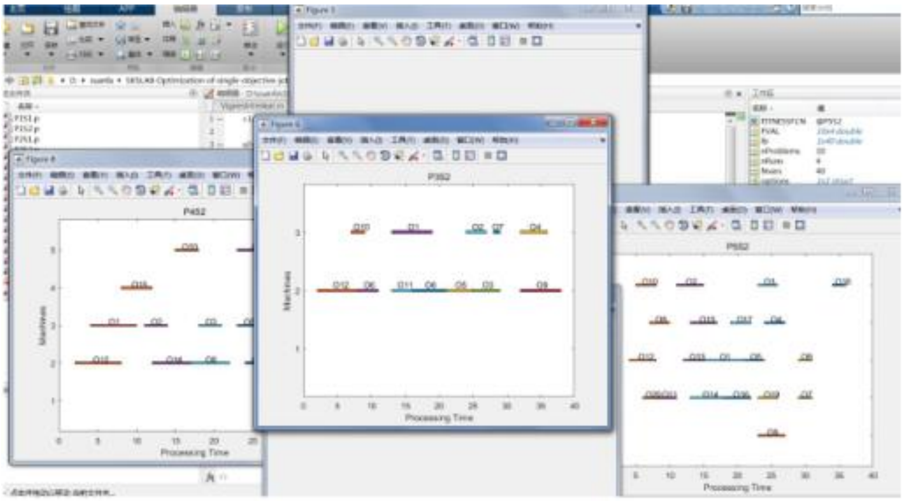

Figure 2

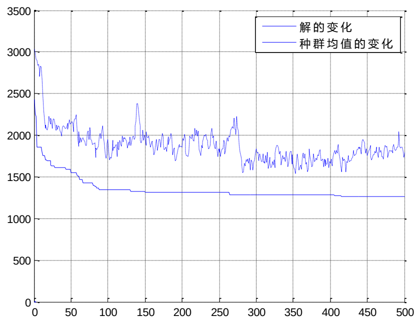


Figure3

## 4. Simulation research on job shop production scheduling based on flexsim software

### 4.1 Simulation description of job shop production scheduling optimization problem

The workshop adopts the way of process layout, the main process procedures are the inspection of raw materials, parts of the car, milling, boring, grinding, pliers, heat treatment and so on. The detailed layout of the workshop is shown in Figure 1. The process flow of two main parts processed in this workshop and the time consumed by each machining process are shown in Table 1.

The facilities in the workshop are replaced by entities in FLEXSIM, 12 generators are used to replace the arrival of raw materials, 6 buffers with 200 units are used to replace the temporary storage area of 12 raw materials, 2 processors are used to replace the inspection of two raw materials in the raw material inspection area, 6 processors are used to represent the inspection of two finished products in the finished product inspection area, and one is used to replace 200 units. Quarantine area. Machining area (turning, milling, grinding, etc.) is represented by a processor for each process. For example, the lathe area needs six turning processes, and the six processors are used to represent the processes of these six lathes. Modeling in Flexsim according to workshop layout .

Procedures are closely linked, and the distance between product inspection areas is too large, which results in a long hauling route and a waste of hauling time.

Table 1

| Object | content | Idle（s） | Processing（s） | Blocked（s） |
|---|---|---|---|---|
| ProcessorJ1 | 1 | 3855.46 | 14735.49 | 10217.18 |
| ProcessorQ2 | 1 | 13123.60 | 12713.31 | 2980.73 |
| ProcessorQ1 | 1 | 6651.58 | 14691.97 | 7474.09 |
| ProcessorC6 | 1 | 7351.08 | 16997.09 | 4469.47 |
| Rack2 | 69 | 0 | 0 | 0 |
| Rack1 | 47 | 0 | 0 | 0 |
| ProcessorJ2 | 1 | 4062.30 | 14516.75 | 10251.77 |
| Queue13 | 0 | 0 | 0 | 0 |
| ProcessorX1 | 1 | 4262.32 | 20512.72 | 4042.59 |
| Transporter1 | 0 | 21334.39 | 0 | 0 |
| | | | | |

### 4.2 Introduction to simulation

FlexSim is a Windows-based, object-oriented simulation environment, which is used to establish discrete event process. FlexSim can describe almost all processes, regardless of production system, office work, logistics and transportation, can be represented by entities in the software model library. The main interface of the software includes menu, entity library, projection model window and work bar. We can start modeling by dragging the entities we need directly from the entity library, which is very simple and convenient.

### 4.3 Simulation research on production scheduling of Z crankshaft company

According to the main functions of distribution center, it is set up into eight areas: receiving area, delivery area, cargo storage area, pallet temporary storage area, picking area, circulation processing area, return area and management control area. In the planning of distribution center, each area is an operation unit.

In the simulation of this paper, we add six generator models to the model, extract three temporary intervals from the model, add six shelves to the model, add one temporary area to the model, add four processors and four recorders to the model, and add one absorber to the model, as shown in the figure.

Step 1: Place a visualization tool in the model view

The visualization tool is displayed with Flexsim GP bitmap texture. To add entities to the container, simply drag them out of the library and place them on the visualization tool.

Step 2: Drag and drop a temporary area and two processors into the visualization tool

When an entity is placed on a visualization tool, it is automatically placed in the visualization tool. You can test this by selecting a visualization tool and moving it with a mouse. When you move a visualization tool, the entities inside it also move along.

Step 3: Drag and drop a generator and an absorber into the model view

When placing generators and absorbers in the model, make sure they are not on visualization tools, and that they are outside.

Before establishing port connections for this example, enlarge the graphical display of port connections, which may be helpful in understanding the two ways of working with containers.

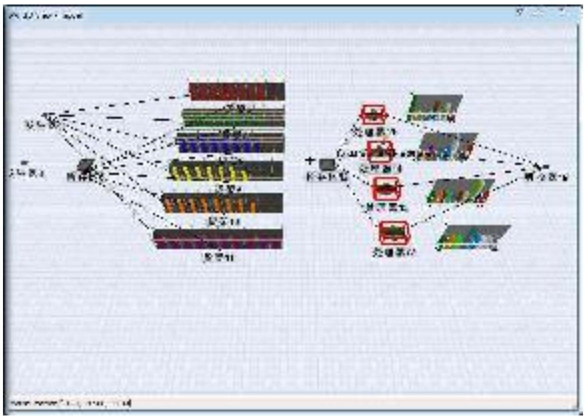

Figure 4-1

The perspective of the overall operation is shown in the following figure. The direction and orientation of the scheduling can be clearly seen in the diagram. To a certain extent, semi-automation tools and scheduling hierarchy are used to solve the disorder and duplicate labor force of logistics. Corresponding settings are made at important nodes to improve the forward speed of logistics.

The existing schemes in actual operation make the phenomenon of finished product waiting less likely. Because the problem of this system is based on the number of service desks open and employee service capacity, the original scheme of opening four service desks can effectively solve the queuing problem and employee error problem to a certain extent, but through statistical analysis, it is found that the number of service desks 4 has a high idle rate and less number of customers to deal with. It indirectly increases the cost of services. For this reason, we have improved it.

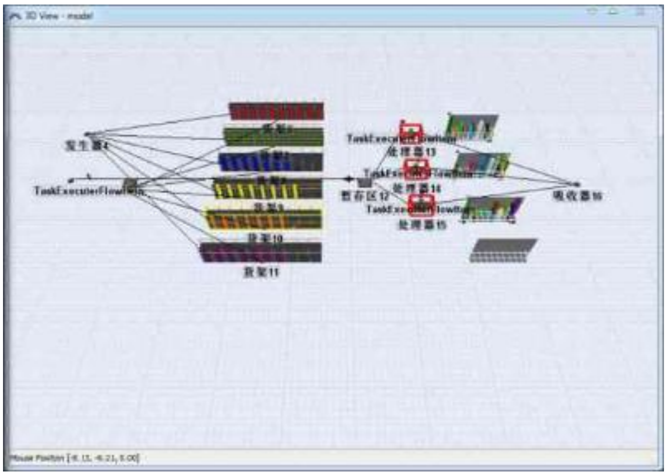

Figure 4-2

## 5. Conclusion

Through comparison, we can see that the design can not only reduce the waiting time of finished products, but also improve the level of profitability of products.

<1>.Keep enough accuracy. The model should reflect the essence and remove the non-essence without affecting the reality of the model.

<2>. Simple and practical. The model should be accurate and simple. If the model is too complex, one is difficult to generalize, and the other is expensive to solve.

Reference to the standard form as far as possible. In the simulation of some real objects, if possible, we should try to draw on some models in the form of standard inference, which can make use of existing mathematical methods or other methods to help solve the problem.

<3> Improve efficiency. With the limited service desk, the working length can be reduced under the condition of maximum utilization.

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