Production Efficiency Management Based on Industrial Engineering Theory and Simulation and Optimization of Steel Wire Braided Hydraulic Hose Production Line

Zhijian Zhang[1], Mingsen Qian[1,*] Lei Chen[2], Chang Liu[1]

[1] School of Transportation and Logistics, East China Jiaotong University, Nanchang, China.
[2] Organization and Human Resources Department, East China Jiaotong University, Nanchang, China.
[*]Corresponding author. Email: 1952276101@qq.com

ABSTRACT

Taking the steel wire braided hydraulic hose production line of an enterprise as the research object, to find the bottleneck process of the production line, and carry out the production efficiency management of the bottleneck process, in this paper, the modelling and Simulation of steel wire braided hydraulic hose is carried out by using the AnyLogic software. According to the results of modelling and simulation, the production process with low production efficiency is found. Then, the production line of steel wire braided hydraulic hose is optimized by using ECRS principle and operation analysis in production efficiency management, and the optimized production line of steel wire braided hydraulic hose is modelled and simulated again by using AnyLogic software. The results showed that the production efficiency, production line balance rate and production capacity of bottleneck process are improved through production efficiency management and modelling and Simulation of AnyLogic software. It can be used as a reference for other steel wire braided hydraulic hose manufacturers.

Keywords: *Steel Wire Braided Hydraulic Hose Production Line, Production Efficiency Management, AnyLogic Software, ECRS Principle, Operation Analysis.*

1. INTRODUCTION

With economic globalization and the rapid growth of my country's economy, the goals of domestic manufacturing companies have changed, from the previous focus on production scale, gradually shifting to improving production efficiency, improving product quality, and reducing production costs [1]. Production line balance refers to the technical means and methods for averaging all the production processes and adjusting the work load so that each work time is as close as possible [2].

At present, there are three aspects in the research of production efficiency. One is to apply the optimization method. Zhao Yanlin, he Xiaoyan and he Jie use genetic algorithm to optimize the design of furniture production line [3]. In addition, some scholars used simulation software, such as Flexsim and witness, to optimize the balance of the production line [4]. Gong Lixiong, Tan Guo and Huang Min simulated and optimized the motorcycle coating production line of a certain enterprise, and carried out secondary optimization for the process bottleneck in the model, so that the motorcycle painting production line reached balance [5]. Thirdly, the industrial engineering theory, such as "5W1H", "ECRS", man-machine operation analysis and other methods, is applied to improve the production line balance [6]. Zhu Huabing, Wang long, Tu Xueming and Yu Feng used the man-machine joint operation analysis method and ECRS principle, combined with the reorganization of operation elements, and applied Em-plant simulation software to doube per capita capacity and improved bottleneck process efficiency [7, 8].

This paper used the AnyLlogic software to model and Simulate the steel wire braided hydraulic hose production line .The production line is optimized, and the optimized scheme is modelled and simulated again. The results show that the optimized scheme reduces the time of bottleneck process, improves the balance rate of production line and increases the production efficiency.

2. MODEL OF STEEL WIRE BRAIDED HYDRAULIC HOSE PRODUCTION LINE BASED ON ANYLOGIC SOFTWARE

2.1. Introduction to AnyLogic Software

AnyLogic software is a widely used simulation software. Its application fields include logistics, transportation, machinery, chemical industry, sewage treatment, telecommunications, military, education, etc. It is a modeling and simulation tool integrating discrete, continuous and hybrid systems. [9]. AnyLogic software provides customers with a unique simulation method, that is, running model simulation on any Java-supported platform or on a Web page [10]. AnyLogic software is the only visualization tool that can create a real dynamic model, that is, a dynamic model with a dynamic development structure and interconnections between components [11].

2.2. Introduction to the Steel Wire Braided Hydraulic Hose Production Line

This paper takes the steel wire braided hydraulic hose production line as an example to establish the production line model.Theprocess includes rubber mixing, inner pipe pressing out,medium rubber forming, steel wire stranding, steel wireweaving, rubber wrapping, cloth wrapping , vulcanization, cloth stripping, pressure test and Core removing, inspecting and packaging.

2.3. Model Assumptions

(1) The company only produces one specification of steel wire braided hydraulic hose, such as 10mm SAE standard steel wire braided hydraulic hose.

(2) The model of steel wire knitting machine is 20.

(3) There are many kinds of raw materials for steel wire braided hydraulic hose, and the production process is complex. In the actual production, 0.1064kg of inner rubber and 0.023kg of medium rubber are required for the production of 100m 10mm steel wire braided hydraulic hose in the rubber mixing link, 10.64kg of inner rubber and 2.3kg of medium rubber are required for the production of 100m. It takes 12.8 minutes to produce 80kg inner rubber and 10.8 minutes to produce 80kg middle rubber. In order to simplify the model, the working time of inner rubber and middle rubber is 2.1 minutes. The same is true for the process of medium rubber forming and steel wire weaving

(4) Steel wire weaving process is 9 hours a shift, 2 shifts a day, and other processes are on a shift. In order to simplify the model, the steel wire stranding process and the steel wire weaving are set to one shift, and time are reduced by half.

(5) The production unit of the model is m.

(6) Raw materials are continuously obtained and will not be shut down due to human or equipment reasons [12].

(7) In the process of medium rubber forming, defective products are considered, and other links are not considered.

(8) A buffer area is set before each process, and the workpiece is transported to the buffer area of the next process after the completion of the previous process, and the handling time of the two processes is not considered [13].

2.4. Parameter Setting of Each Process

The parameter setting of each process is shown in Table 1, and the process flow chart is shown in Figure 1.

Table 1. Parameter setting of each process

Serial number	working procedure	Number / person	Number of equipment / set	Processing / *m*	man-hour /*min*
1	rubber mixing	4	1	100	2
2	medium rubber forming	2	1	100	2.5
3	inner pipe pressing out	3	1	100	3.5
4	steel wire stranding	2	4	17.5	0.6
5	steel wire weaving	3	9	100	5
6	rubber wrapping	3	1	100	3.5
7	cloth wrapping	1	1	100	5
8	vulcanization	1	1	4000	180
9	cloth stripping	1	1	100	5
10	pressure test and Core removing	1	2	100	2.6
11	Inspecting and packaging	2	1	100	3

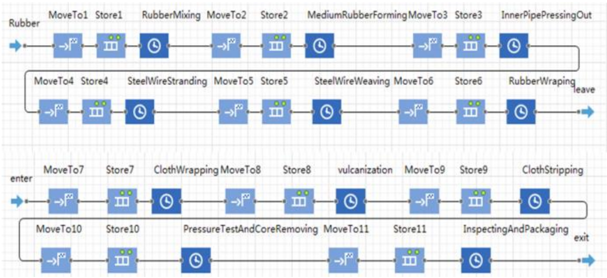

Figure 1 Production simulation model of steel wire braided hydraulic hose

2.5. Analysis of Simulation Results

The time unit of the model is minutes, because the working hours of some processes are long, such as the vulcanization process, which takes 180 minutes. When the model runs to 214 minutes for inspection and packaging, a unit of product is processed. The simulation time of the model is set as 60 * 9 = 540 minutes, which is less than the target capacity. Therefore, the model simulation is set at 214 + 540 = 754 minutes, and the simulation output shows that the production is 10784.

Production line balance rate = [total time of each process / (CT * number of processes)] * 100%

CT: the maximum standard man hour in the production line process [14].

The balance rate of the production line is 72.72%, and production efficiency is low.

3. OPTIMIZATION OF PRODUCTION LINE OF STEEL WIRE BRAIDED HYDRAULIC HOSE

3.1. Introduction of Program Analysis in Industrial Engineering

The four principles of program analysis in industrial engineering are E (Eliminate), C (Combine) R (Rearrange) S (Simplify) .Elimination, which means eliminating unnecessary processes or operations; Combination means Combining several processes; rearrangement is to change the sequence of processes and operations; simplification is simplification of technology and operation [15]. This paper uses ECRS principle and operation analysis in production efficiency management to optimize the production line of steel wire braided hydraulic hose.

3.2. Improvement of Rubber Mixing Process

Before the production of internal rubber and medium rubber, four employees were equipped with small medicine, powder, carbon black, handling, cutting and weighing Polymerized Styrene Butediene Rubber and Nitrile Butadiene Rubber respectively.

The transportation route of Polymerized Styrene Butediene Rubber and Nitrile Butadiene Rubber was adjusted. The original operation was that the warehouse handling personnel carried the Polymerized Styrene Butediene Rubber and Nitrile Butadiene Rubber to the storage area located in the north wall of the mixing workshop, and the personnel responsible for handling, cutting and weighing pulled the Manual hydraulic truck to the storage area, and transported the Polymerized Styrene Butediene Rubber and Nitrile Butadiene Rubber from the pallet to the Manual hydraulic truck, and pulled the Manual hydraulic truck back to the side of the rubber cutter for rubber cutting operation. The transportation route was adjusted, and the warehouse handling personnel directly sent the Polymerized Styrene Butediene Rubber and Nitrile Butadiene Rubber to the side of the rubber cutting machine, and the loading and unloading operation was omitted. Taking the production of 31 car inner rubber and 12 car medium rubber in a day as an example, it needs 36 pieces of rubber, 9 pieces of rubber are transported at a time, saving 22 minutes. The operation of handling, cutting and weighing is reduced from 94 minutes to 72 minutes.

The longest time with small chemicals is 115 minutes. Rearrange the process of dispensing small chemicals. After the completion of handling, cutting and weighing, the staff will help the staff with small chemicals to carry out auxiliary work. The staff will carry the small chemicals needed for the next day to the batching room, and at the same time, they will transport the prepared small chemicals to the internal mixer, and the weighed sulfur to the open mill. The time of preparing small chemicals decreased from 115 minutes to 89 minutes, and the working hours of handling, cutting and weighing increased from 72 minutes to 98 minutes. The time of inner rubber mixing decreased from 12.7 minutes to 12.3 minutes, and the time of medium rubber mixing decreased from 10.7 minutes to 10.3 minutes.

3.3. Improvement of Medium Rubber Forming Process

The problem of medium rubber forming process is that the thickness of the medium rubber is different, and there is no inspection link after the production, which is directly used in the steel wire knitting machine. The thin medium rubber will break when steel wire knitting machine is wove, causing the staff to inspect frequently and replace the medium rubber. For this reason, the process of medium rubber forming was improved.

There are three operations in the process of medium rubber forming. In the first operation, the medium rubber is put into the open mill to preheat and roll. In the second operation, the medium rubber is put into the Three Roll Calendar for calendaring. The third operation is to cut into medium rubber as required. Each kilogram of medium rubber takes 0.5 minutes, 0.38 minutes and 0.6 minutes respectively. Affect the film thickness in the first and second operations. In the first operation, the staff put 10kg of medium rubber into the opening machine for preheating at one time.

The input amount exceeded the capacity of the drill machine, resulting in slow discharging and slow glue eating. At the same time, the preheating of some medium glue was not sufficient, the rubber material was hard and the medium pressure was uneven in the rolling stage. Affecting the thickness of medium rubber is in the first and second operations. In the first operation, the staff put 10kg of medium rubber into the opening machine for preheating at one time. The input amount exceeded the capacity of the opening machine, resulting in slow discharging.

At the same time, the preheating of some medium rubber was not sufficient, the rubber was hard and the thickness of rubber is inconsistent in the calendaring stage. In the second operation, the employees did not have a temperature measuring gun and could only measure the temperature roughly by hand. The measured temperature was not accurate. When the temperature is too high or too low, the thickness will be uneven, and the temperature will also cause the rubber to burn. To improve the operation of the first step, cut the 10kg medium rubber into two 5kg medium rubber. The input amount is reduced by half, so that the preheating is sufficient and the preheating time is accelerated. The preheating time is reduced from 3.6 minutes to 3 minutes, and the working hours per kilogram of medium rubber molding is reduced from 1.1 minutes to 1 minute. In the second step of operation, use a temperature measuring gun to accurately measure the temperature, and keep the temperature at 55°C-65°C on the upper roller and 45°C-55°C on the lower roller. The product return rate has been reduced from 5% to 1%.

3.4. Improvement of Steel Wire Weaving Process

The steel wire braiding process is a bottleneck process, and the output is increased by adding one machine.

The steel wire braiding process is to check the outer diameter of the inner tube, the number of strands, the width and thickness of the middle rubber, and then carry out the on-line operation, and put the middle rubber and the inner tube into the braiding machine. After that, employees began to inspect. The inspection content is to check whether the inner tube is braided, whether the spindle is damaged, whether the middle film wraps the inner tube, whether the thread is disordered, broken, and the braided diameter is formed. Three people operate 9 machines, and one person operates 3 machines as an example. The employees inspect the first machine, the second machine, and the third machine in 2 minutes and 40 seconds. Then return to the first machine to inspect.

3 people operate 10 machines, and the 10th machine is operated by a third person to reduce working hours. The company purchased a high-speed weaving machine and a stranding machine in 2019. The quality of the weaving machine and stranding machine is good, and the hang difference of the stranding is small. The spindle of the weaving machine is not easy to damage, the spindle pay-off tension is stable, the frequency of disordered threads and broken threads is small, and the braided diameter is formed well. At the same time, the process optimization is carried out in the middle rubber forming process, so that the middle rubber thickness is consistent, the middle rubber does not break, and the inner tube can be tightly wrapped, so it can reduce the number of times the staff solve the fault. According to the actual operation, the staff is operating 4 machines, Can deal with the problem in time, guarantee the normal production of 4 machines. The wire weaving time is reduced from 5 minutes to 4.5 minutes.

3.5. Improvement of Cloth Wrapping and Cloth Stripping Process

The cloth wrapping and cloth stripping processes are bottleneck processes, which reduce the working hours by increasing the width of the cloth. The original operation is used as 70mm cloth. In order to improve the efficiency of the process of cloth wrapping and cloth stripping, 80mm r cloth is used. The working hours of the cloth wrapping and cloth stripping were reduced from 5 minutes to 4.4 minutes.

3.6. Evaluation of Improvement Scheme

The improved parameter setting of each process is shown in Table2.

The simulation of the improved production line is carried out by the AnyLogic software. The working time of bottleneck process was reduced from 5 minutes to 4.5 minutes, and the balance rate was increased from 72.72% to 76.76%.The output is 10784 before improvement and 12035 meters after improvement, which increases the production efficiency. The equipment utilization rate of vulcanization and pressure test and Core removing and inspecting and packaging increased from 0.76, 0.38 and 0.43 to 0.85, 0.42 and 0.48 respectively. The average queue length of steel wire weaving area is reduced from 1200 to 400. As shown in the Figure 2, Figure 3, Figure 4, and Figure 5.

Table 2. Improved parameter setting of each process

Serial number	working procedure	Number / person	Number of equipment / set	Processing / *m*	man-hour /*min*
1	rubber mixing	4	1	100	1.9
2	medium rubber forming	2	1	100	2.3
3	inner pipe pressing out	3	1	100	3.5
4	steel wire stranding	2	4	17.5	0.6
5	steel wire weaving	3	10	100	4.5
6	rubber wrapping	3	1	100	3.5
7	cloth wrapping	1	1	100	4.4
8	vulcanization	1	1	4000	180
9	cloth stripping	1	1	100	4.4
10	pressure test and Core removing	1	2	100	2.6
11	Inspecting and packaging	2	1	100	3

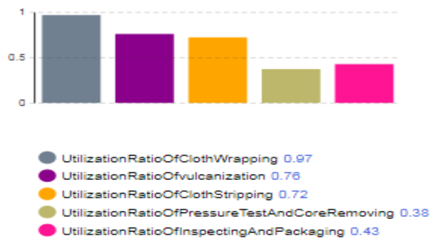

Figure 2 Equipment utilization before improvement

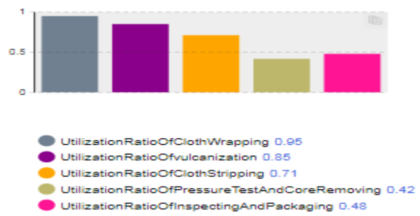

Figure 3 Equipment utilization after improvement

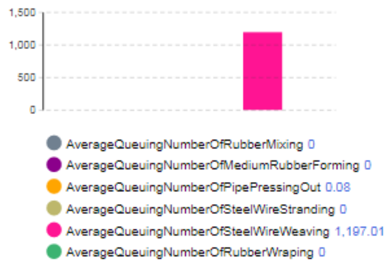

Figure 4 Average queuing number before improvement

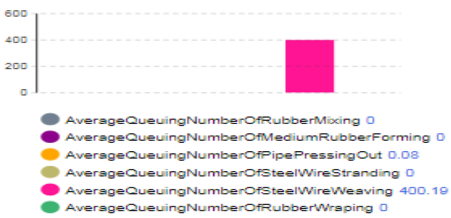

Figure 5 Average queuing number after improvement

4. CONCLUSION

Taking the steel wire braided hydraulic hose production line as an example, the modelling and simulation are carried out by using the AnyLogic software. Using ECRS principle and operation analysis in production efficiency management optimize the steel wire braided hydraulic hose production line. The working time of bottleneck process was reduced from 5 minutes to 4.5 minutes, and the balance rate was increased from 72.72% to 76.76%, and the output was increased from 10784 to 12035 meters after improvement. The innovation of this paper is to improve the quality of medium rubber, reduce the times of medium rubber breaking and replacement in steel wire weaving process, reduce the workload of employees, and the staff can operate one more machine. One improvement can improve other processes. It can be used for reference for similar steel wire braided hydraulic hose enterprises.

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