Research of Auto Parts Assembly Line Simulation and Optimization Based On TOC

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Abstract. In view of the current situation of auto parts industry and the characteristics of assembly line, this paper adopts the constraint theory to study. Through the arena modeling and simulation means to find the "bottleneck" of the auto parts enterprise assembly line. And then develop the optimization program for eliminating or transferring the "bottleneck". And use ECRS (Eliminate, Combine, Rearrange, and Simplify) analysis to improve the entire assembly process. Achieved the purpose of optimizing the allocation of resources and improving the rate of output.

1. Introduction
Auto parts industry holds a very important position in China manufacturing industry. With its scale gradually expanding, the present and future situation of auto parts industry is more and more related to the stability and development of China’s industry. Faced with personalized demand, fluctuant order and unstable supplier quality, it is an urgent topic for auto parts enterprises to find out how to improve the productivity and resource utilization in order to improve production profit. [3]

Research shows that bottleneck identification and transfer in production system is one of the most important methods for production system improvement. The TOC (Theory of Constraints) includes a set of methods to improve restraints and bottlenecks. The basic concept of TOC includes three parts: bottleneck, target and evaluation standard, in which the concept of bottleneck is the core of TOC. The theory defines the goal of the enterprise, that is, "the present and the future are profitable". On this basis, the enterprise performance is measured by examining the sales-output ratio, inventory and operating expenses of the enterprise. [1] [2] [3]

In this paper, the TOC thinking program and modeling simulation are combined to improve the whole auto parts assembly line, aiming at optimizing the allocation of resources and improving the output rate. There are two innovations:

From the perspective of TOC, using computer modeling and simulation method to identify the bottleneck and optimize, and using ECRS analysis to improve the whole assembly line. This paper makes innovations in the synthesis of methods.

In view of the specific enterprise and the target workshop, using the theoretical knowledge to guide the practical problems, this paper solves the negative impact of the production system bottleneck in the
workshop of manufacturing enterprise, which brings a certain degree of profit promotion for the enterprise and has reference significance in practical application.

2. Technical Route

The technical route of this research is shown in Fig. 1. On the basis of summarizing the domestic and foreign literature, the research has accumulated the relevant theoretical knowledge, including the TOC, the computer simulation [4] [6] and the assembly production system. On the other hand, we proceed to investigate the actual situation of the target enterprise, and observe the production system, collect relevant data, and search for enterprises resources that can be used to improve the system. Theory and research, the knowledge is applied to the real system, through the qualitative analysis and simulation of the production system to determine the bottleneck of the production system and the direction of improvement, and then use the existing resources to optimize, reach to the purpose of the enterprise to increase profits.

3. Modeling and Simulation

3.1. Company a profile and the importance of assembly lines

Company A is located in Guangzhou City, which is a factory specializing in the production, processing and sale of assemblies and parts of heavy-duty vehicle brake system. It specializes in the production of brake manual adjustment arm, brake automatic adjustment arm, single chamber, spring break chamber
and its related parts, which related to internationally famous brands such as HALDEX, BENDIX, DAF, BPW, etc. corresponding to the original model. These products are of excellent quality, mainly exported to European and American market.

Product assembly is an important part of the production process. The quality of the assembly directly determines the quality of the final product. [5] The assembling work is a process of combining a set of fragmented parts through a reasonable technological process and the necessary means, in accordance with the certain accuracy standards and technical conditions. It is more complex than the machining. Assembly lines often vary by product, according to the product structure, requirements for assembly accuracy, customer requirements for product quality. Different assembly lines have different organizational requirements for the production process, such as equipment, staff skills, production-line technique, production parameter design, etc. So the assembly line does not just affect the assembly operations. At the same time, it requests the whole production process. [7]

3.2. Assembly process analysis of spring break chamber

Due to the actual needs of customers, there are two kinds of spring break chamber assembly products in company A: semi-assembly and assembly. After long-term practice, assembly production technology has been fully affirmed. The workers are very skilled in their operations and have few mistakes, so the simulation ignores the impact of artificial errors on the assembly process. After communication and observation, we sort out the semi-assembly, assembly of the two assembly process, as shown in Figure 2, Figure 3, and a total of twenty-two steps. The processing time of each step is shown in Table 1. In actual production, the semi-assembly or assembly is selected according to the customer's needs.

![Figure 2. The semi-assembly process](image)

![Figure 3. The assembly process](image)
3.3. Build the Simulation Models and Then Run
Simulation modeling is based on the actual operation of the object to build the model. [4] [6] [8] Based on the working procedure of assembly process and the mathematical distribution of their processing time, the simulation model is established in Arena software. [9] [10] A variety of key parts are mixed together to reach the assembly production system. The time between arrivals of the semi-assembly, and the assembly process simulation is averaged to an exponential distribution of 17, 26.9 (in seconds). The Simulations run for 8 hours.

3.4. Analyze the Simulation Results and Identify “Bottlenecks”
The semi-assembly process from the entity report of the simulation, as shown in Figure 4(a), we can see that: during the simulation, there are 1610 entities entering the system, 1478 entities leaving the system, and an average system stay of 1421.91 seconds. It can be seen from Figure 5(a), entity in step 1 was waiting for up to 1238.09 seconds, far greater than in other steps. This shows that step 1 has been unbearably busy and it is the bottleneck of the simulation. And it is also known from the resource output report (as shown in Figure 6(a)) that the scheduled utilization of resource 1 is the largest, its value is 1, indicating that the step 1 is too busy to meet the production needs and it is the bottleneck process.

The assembly process From Figure 4(b) we know, during the assembly process simulation, there are 1030 entities entering the system, 950 entities leaving the system, and an average system stay of 1394.36 seconds. It can be seen from Figure 5(a) that entity in step 8 waiting for the longest time, up to 1107.24 seconds. So step 8 is the bottleneck process in this simulation. In Figure 6(b), the scheduled utilization of resource 8 is the largest, its value is 1. So step 8 is the bottleneck process.

In summary, in the semi-assembly assembly process, the step 1 is the bottleneck process. In the assembly process, step 8 is the bottleneck process.

![Figure 4. The simulation results on entity](image)
Figure 5. The simulation results on queue

Figure 6. The simulation results on resource
4. Optimization
According to TOC, the loss time of bottleneck process is equivalent to the loss time of the entire process. So the improvement of the assembly process can be improved from the constraints and bottlenecks. And use ECRS analysis to simplify or cancel some small, less impact-prone processes. On one hand is to reduce the workload, on the other hand is to reduce the error caused by the unnecessary interference.

4.1. Research on the Improvement of Bottleneck
TOC’s thinking process is implemented by answering three questions: "what to change", "change to what", "how to change". "What to change" means to determine a core problem. Find all the behavior of the constraints is equivalent to understand the problem. "Change to what" is for the core problem has been found, to put forward what it would look like. "How to change" is to think through what methods to change the problem into the desired state.

Step 1 is to install O-rings. This step is necessary. After observation, the cause of the bottleneck of the step is the need to carry parts during operation. Before the operation, first move the parts and cancel the workers’ handling operation, can save a lot of time. After several times, the operation time of step 1 can be adjusted to an average of 10 seconds, greatly reducing the process time.

Step 8 is to install a large spring. As can be seen from Table 1, the operation time of step 8 is much longer than that of other steps. Taking into account the need to double the operating speed of step 8 in order to rational use of the subsequent resources. At the same time taking into account the actual economic situation, the workshop space and the facility placement of company a, we add a set of the same machine for step 8, while not reducing the number of other operating equipment.

4.2. Modification and Re-simulation of Simulation Model
ECRS analysis provides a way to build and improve the production process. It raises four questions in building a process. According to these four questions to determine the process needs to be improved. Systematically analyze the actual situation of assembly line, simplify or eliminate steps that have little impact on the entire production process, to propose an effective optimization program for the enterprise's production process and to save costs at most while improving profits.

The entire assembly process is carefully studied once again. After discussing, the step 12 and the step 16 are considered to be repetitive work and can be eliminated.

Carefully studied the step 6 and determined that it spend a bit more time at the first time. At the first time, the workers must take the bottom chamber, and then put down the chamber plates, studs, and finally put the whole work piece into the machine to press. While the machine is working, the workers lay down the next chamber’s plates and studs. After the machine is completed, the next work piece can be directly into the machine. After several times, we can see that the processing time of step 6 can be simulated using trigonometric function TRIA (13, 16, and 19).

Step 7 is to install the semi-assembly. There are many parts to be transported before operation, including the middle chamber, bottom chamber, riveting bolts, clamp ring nuts & bolts, and so on. It is time-consuming slightly more. Prepare the required parts before operation, can be appropriate to reduce the process time. After improvement, we can see that the processing time of step 7 can be simulated using trigonometric function TRIA (13, 16, and 20). Similarly, the processing time of the improved step 9 can be simulated using the trigonometric function TRIA (14, 17, and 20).

The processing time of each step is shown in Table 1:
Table 1. Steps and Their Processing Time

| Step Num. | Operation content                                      | processing time before optimization | processing time after optimization |
|-----------|--------------------------------------------------------|-------------------------------------|-----------------------------------|
| 1         | Install O-rings TRIA(16,19,23)                         | TRIA(7,10,13)                       |
| 2         | Type the middle chamber TRIA(5,7,9)                    | TRIA(5,7,9)                         |
| 3         | Paint the push rod TRIA(12,15,18)                      | TRIA(12,15,18)                      |
| 4         | Rivet spindle push plate TRIA(11,13,15)                | TRIA(11,13,15)                      |
| 5         | Rivet spindle push plate of the middle chamber TRIA(12,15,18) | TRIA(12,15,18)                      |
| 6         | Press rivet stud of the bottom chamber TRIA(13,17,21)  | TRIA(13,17,21)                      |
| 7         | Install the semi-assembly TRIA(15,19,23)               | TRIA(13,17,21)                      |
| 8         | Install a large spring TRIA(24,30,36)                  | Add a set of machines TRIA(14,18,22) |
| 9         | Set assembling TRIA(14,18,22)                          | TRIA(14,18,22)                      |
| 10        | Rivet clamp bolt TRIA(11,15,19)                        | TRIA(11,15,19)                      |
| 11        | Take out the pull rod TRIA(13,16,19)                   | TRIA(13,16,19)                      |
| 12        | Artificially tight the clamp nuts again TRIA(3,5,7)    | Cancel the step                     |
| 13        | Install dust cap of the top chamber TRIA(2,4,6)        | TRIA(2,4,6)                         |
| 14        | Install spring washer, weld nuts, lock nut TRIA(9,12,15) | TRIA(9,12,15)                      |
| 15        | Install pull rod, pull-rod washer and pull-rod nut TRIA(11,15,19) | TRIA(11,15,19)                      |
| 16        | Visual inspection and repair TRIA(3,4,6)               | Cancel the step                     |
| 17        | pack semi-finished product TRIA(10,13,16)             | TRIA(10,13,16)                      |
| 18        | steel strips for semi-finished package TRIA(8,10,12)  | TRIA(8,10,12)                      |
| 19        | Stuffing container for semi-finished product TRIA(10,13,16) | TRIA(10,13,16)                      |
| 20        | pack assembly product TRIA(12,15,18)                   | TRIA(12,15,18)                      |
| 21        | steel strips for assembly package TRIA(12,15,18)       | TRIA(12,15,18)                      |
| 22        | Stuffing container for assembly product TRIA(10,13,16) | TRIA(10,13,16)                      |

According to TOC, the loss time of the bottleneck step is equivalent to the loss time of the whole process. Similarly, the saved time of the bottleneck step is equivalent to the saved time of the whole process. So it can shorten the time between arrivals of the optimized simulation model. The time between arrivals of the optimized semi-assembly, assembly simulation, respectively, obey the exponential distribution of the mean value of 16, 17 (in seconds).

4.3. Analysis of Optimized Simulation Model Results

As can be seen from Figure 4(c), the simulation system runs for 8 hours a day. In the simulation process, there are 1700 entities into the system and 1687 entities leaving the system. When the semi-assembly process is optimized, the output increases (1687-1478)/1478≈14.14%.

It can be seen from Figure 6(c), each step’s scheduled utilization of the optimized semi-assembly process simulation has changed, relatively large load process of which is the step 7 and step 6. Their scheduled utilization is 0.96, 0.94.
As shown in Figure 4(d), the optimized assembly simulation system runs for 8 hours a day. In the simulation process, there are 1716 entities entering the system, 1659 entities leaving the system. And the output increase \((1659-950)/950=74.63\%)\, greatly improving the system's output.

It can be seen from Figure 6(d), each step’s scheduled utilization has changed, the largest load process of which is the step 9. Its scheduled utilization is 0.98. The bottleneck process has shifted.

Through the analysis, it can be seen that the optimized assembly line has been improved obviously in resource utilization and production yield, and the efficiency of assembly has been improved. It is proved that the combination of simulation technology and TOC and ECRS analysis has a certain degree of reliability for solving the balance problem of actual assembly line.

5. Result Comparison

The TOC and the Arena simulation method aimed to improve the productivity and resource utilization for auto parts enterprises. It can be seen that using the Arena simulation method to find the bottleneck, and using the TOC, ECRS analysis to optimize, can achieve the purpose of optimizing the allocation of resources and improving the level of productivity. Furthermore, the theory and the method can be completely extended to other production line.

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