Balancing Optimization of Motor Production Line Based on Industrial Engineering Approach

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Abstract: In order to solve the motor production line balance is low, low production efficiency, production capacity can not reach the expectations, the high rate of worker operation error. In this paper, the industrial engineering process analysis method, the ECRS principle, the "5W1H" and the implementation of 6S field management are adopted to improve the overall production operation of the production line and the operation content of some work units. The balance rate of the production line was increased from 71.72% to 78.23%. In terms of balance rate, the improved production line has a better effect than before, which makes the production line reach the scientific management level and provides a reference for the improvement of similar production line balance. It has important theoretical significance for the research results in manufacturing field, and has practical value for enterprises.

Keywords: production line balance;industrial engineering;6s management; production line optimization

1 Introduction

Currently, assembly line production is one of the main production methods of manufacturing enterprises production line load, in order to make the time of each operation as similar as possible technical means and methods. The purpose is to eliminate the efficiency loss of imbalance between operations as well as overproduction. Production line balancing is a big learning, and production line balancing is directly related to the normal use of production lines. The production line balancing guide mainly includes the relevant definition of production line balancing, the meaning of production line balancing, the calculation of process balancing rate, and the principles and methods of production line balancing improvement. Therefore, the optimization and improvement of production line plays an important role in the management and improvement of production line in manufacturing industry. At present, the main research is how to keep the production line in balance [1]. The most applied methods to solve the production line balance problem are traditional industrial engineering approaches and site management methods, but with the depth of research, heuristic algorithms, simulation hair, artificial intelligence algorithms and other methods emerge in large numbers, and they all have their own characteristics, which provides a new direction for the study of production balance problems[2]. For the management and improvement of production lines, in the increasingly competitive market segment, if an enterprise wants to enhance its market competitiveness, it must combine its own actual situation, optimize and adjust the production lines in a targeted manner, match

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the corresponding production lines for different products, so as to improve the production efficiency of the enterprise and promote the enterprise to achieve maximum benefits.

This paper studies a professional factory that develops, produces and sells cylindrical motors and flat motors. At present, in the actual production, there are many in-process inventory, workers' burnout complaints, and high operation error rate. The root cause of these phenomena is the low balance rate of the company's production line, which affects the production of products. The company urgently needed to change the status quo of its production lines and improve its own line balancing rate while ensuring that costs were as low as possible. It was found that the management method used by the company was on-site management, a traditional management method that is relatively homogeneous, and in the actual production process, a single management method can lead to a low production line balance rate. To address this situation, the thesis uses a combination of both on-site management and traditional industrial engineering approaches to improve the balancing problem of the company's motor production line.

2 Analysis of the current situation of the motor production line

With the gradual growth of motor orders, the production line is facing increasing production pressure. There is a great need to optimize the motor production line to reduce production waste, reduce production costs and increase production capacity in order to improve the company's overall production efficiency and increase market competitiveness [3]. The production line has been in operation since February 2020 and has been in use for more than 2 years. Many production problems have occurred since the start of production, so it is necessary to analyze the production process of the company's motor production line using industrial engineering related methods, in order to find the unreasonable production process.

Figure 1 Production diagram of the company's motor assembly

Table 1 Flow chart of motor assembly process before improvement

Workstation	Work process	Number of people	Work content	Average time	Working hours
1	1	1	Winding by automatic winding machine	5	5
2	2	2	Manually pick up coils	20.13	54.11
	3	2	Wire handling and weighing	17.77	
	4	2	Coils dipped in green water, loading coils and dispensing glue	16.21	
3	5	1	Prepare flange	14.56	14.56
4	6	2	Fixing coil and PCB board	6.31	32.19
	7	2	Fixed coil wire head with PCB board	6.24	
	8	1	Checking H-PCB board soldering	4.32	
	9	2	Fixing solder joints and wire headers	12.31	
	10	1	Checking the appearance	3.01	
5	11	1	Install vibrator, bearing	8.33	58.79
	12	1	Installing components	17.32	
	13	1	Injection molded rotor assemblies	20.01	
	14	1	Bearing blowing and cleaning	10.11	
	15	2	Rotor appearance inspection	3.02	
6	16	3	Stator cleaning	6.71	6.71
7	17	2	Mounting flange	5.02	10.23
	18	2	Installing terminals	5.21	
8	19	2	Place rotor	5.03	18.74
	20	2	Release flange, test data	10.50	
	21	3	Set screw	3.21	
9	22	3	Mounting iron sheet, brake gear	13.32	47.3
	23	3	Installing brake screws	10.22	
	24	2	Inserting and playing the support rod	7.09	
	25	2	Installing wind blades, clamping springs	9.37	
	26	2	Installation of wind cover	5.08	
	27	2	Installation of nameplate	2.22	
10	28	1	Whole machine self-test	9.32	9.32
11	29	1	Packaging	7.03	19.05
	30	2	Sealing boxes	12.02	

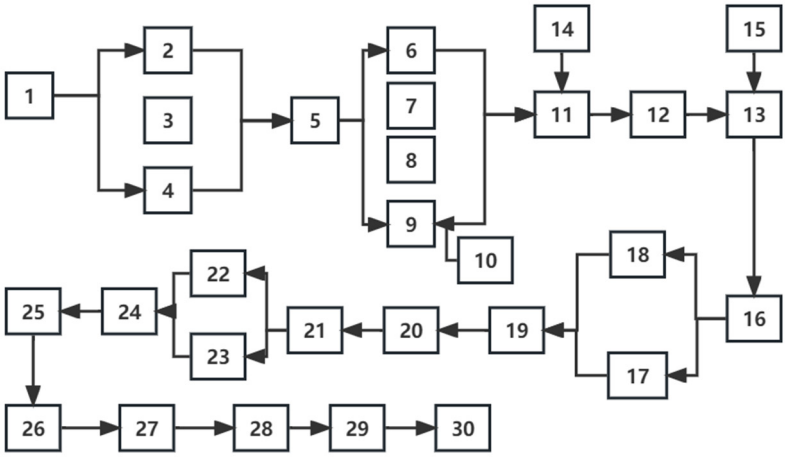

Figure 2 Priority relationship of workflow of motor production line before improvement

Table 2 Standard time of 11 workstations in motor production line

Workstation number	Number of operating personnel	Observation time	Standard operating time	Work time utilization
1	1	5	7.05	67.20%
2	6	54.11	56.21	53.03%
3	1	14.56	17.78	73.12%
4	8	32.19	36.23	82.20%
5	6	58.79	62.21	90.43%
6	3	6.71	9.11	83.21%
7	4	10.23	13.25	60.53%
8	7	18.74	21.23	74.21%
9	14	47.3	50.12	70.61%
10	1	9.32	12.02	52.32%
11	3	19.05	23.45	78.02%
Total	54	276	306.66	70.13%

2.1 Poor effect of work hour utilization

The unreasonable distribution of personnel workstations causes a few workers to work slackly and a few workers to be overloaded, resulting in the generation of bottleneck processes, which leads to workers not being able to produce and assemble in a rhythmic manne[4]. Through Table 2 it is concluded that the workstations with better effect can reach more than 90%, which means that some workstations have serious waste of man-hours and the utilization rate gap between each workstation is large, so the production process can be improved considering the actual situation.

2.2 Production line balance rate is not high

The work time allocation of each process is not balanced, and the difference between process beat times is relatively large. In addition, Table 2 shows that:

the balance rate of the production line :

$$P = \frac{\sum_{i-1}^{N} T_i}{T_{\max} \times N} = 71.72\%$$

the loss rate:

$$IR = \frac{\sum_{i-1}^{N} (T_{\max} - T_i)}{T_{\max} \times N} = 1 - P = 28.28\%,$$

which indicates that the balance rate of the production line is low and there are some areas to be optimized and improved.

3 Production line improvement based on the traditional industrial engineering approach

The traditional industrial engineering approach is a way to improve production efficiency through field inspection of the production line, specific analysis of specific problems, and the use of effective strategies with reduced inputs [5]. It is mainly improved through the following process analysis and 6s management.

3.1 Optimization of production line based on process analysis

Process analysis is an analysis technique that takes the whole production process as the object of study, and studies and analyzes the complete process procedure, from the first workplace to the last workplace, whether there are redundant, repetitive and unreasonable operations, whether the sequence of operations is reasonable, whether the handling is too much, whether the waiting is too long, etc., and formulates an improvement plan. For the process analysis, we ask questions about the problems using the "5W1H". After asking questions, the production process is optimized using the "ECRS" principle. The "ECRS" principle optimizes the production process. Each letter of ECRS represents an optimization approach: Eliminate, Combine, Rearrange, Simplify.

By asking questions about the work processes, we aim to find out the problems that exist in each process, such as improper arrangement and excessive connection of processes. Since there are too many processes, the paper does not show the "5W1H" communication activities for the next processes, but gives a summary of the processes that need improvement.

(1)Process 1, "Guarding the automatic winding machine", can be eliminated because the automatic winding machine usually starts working without problems, so it is considered a waste of human resources to guard it. Therefore, process 12 can be cancelled to reduce the workload(Jackson,1956) Process 15 can be cancelled for the same reason.

(2)Process 2 "manual coil pickup" and Process 3 "wire sorting and weighing" can be combined. Reduce waste of personnel.

(3)Combining processes that operate in the same or similar manner reduces personnel waste. For example, Process 6 and Process 7, Process 9 and Process 10, Process 17 and Process 18, Process 19, etc. can be combined.

A comparison of specific before and after improvements is shown in Table 3.

Table 3 Comparison of before and after process optimization

Work process	Work content	Optimization method	Number of optimizers	Optimization time comparison (s)
1	Guard automatic winding machine winding	Cancellation	1	5/0
2	Manual pickup of coils	Merge	2	20.13/17.83
	Wire handling and weighing			
3	Fixing coils and PCBs	Combined	2	6.31/6.02
	Fixing coil wire head with PCB board			
4	Fixing solder joint and wire head	Merge	1	12.31/11.23
	Check the appearance			
5	Installing oscillator and bearing	Merge	1	17.32/15.33
	Installing components			
6	Rotor appearance inspection	Cancellation	1	3.02/0
7	Mounting flange	Merge	2	15.26/12.22
	Install terminal			
	Put rotor			
8	Installing iron sheet and brake gear	Merge	1	23.54/19.33 57.03
	Install brake screw			
9	Installing airfoil, circlip	Combined	1	14.45/12.23
	Installing the wind cover			
10	Packing	Combined	1	19.04/17.33
	Seal box			

The paper removes and merges some work processes from the point of view of process analysis and gives a series of optimization suggestions for the motor production line. After optimization, the number of work processes, the number of personnel and the total production time were reduced by 11, 13 and 33.29 seconds respectively.

3.2 Promote 6S management.

To implement 6S management in order to promote production, a series of activities were carried out to establish a 6S promotion team to solve irregularities in on-site 6S management; [7](Jinlin Li,2019) to strengthen training for operators to promote operators to consciously identify and solve on-site problems; to optimize the on-site working environment to create a comfortable and neat working environment for on-site operators, which helps to improve their motivation.

(1)Tidy up. Through the establishment of 6S team, the evaluation standard of 6S tidying is formulated so as to standardize and standardize the cleaning of items and reduce the waste in production [8](Li,Jinlin,2019).

(2)The 6S team can make regular inspections, develop a system of rewards and punishments, and also re-establish standards if abnormal conditions occur.

(3)Cleaning. 6S team can develop a regular cleaning schedule, and for each cleaning results for scoring, there are substandard areas to be warned and punished, and arrange for timely rectification.

(4)Quality. 6S team can regularly hold 6S management training courses to promote the knowledge of 6S management to employees, so that employees comply with the company's good norms. The standard is mandatory, and it is most efficient if the mandatory norms are transformed into spontaneous actions of employees.

(5)Safety. Safety is an important guarantee for production, and only by ensuring that site operators operate in a safe environment can personnel work more efficiently [9]. This not only reduces production accidents, but also increases the enthusiasm of production personnel.

4 Evaluation of improvement effect

Before the improvement, the production line had 30 operating units, and after applying the basic industrial engineering approach and genetic algorithm to improve the production line, the operating units were reduced to 19. In the process of production, by simplifying and combining some processes of the production line, the balance rate of the production line was effectively improved and the manpower was reduced. After a series of improvements to the production line, the timing of each process was more balanced to meet customer demand and the production process was more reasonable. The improved line balance rate increased from 71.72% to 78.23%, and the loss rate decreased from 28.28% to 21.77%[10]. In addition, as the processes were streamlined and combined, the line was streamlined with fewer operators, reducing labor costs. After improving the balance of the production line, the balance rate of the production line was significantly improved and the loss rate was significantly reduced. By promoting 6S management and cultivating production improvement thinking among employees, it helps to improve employees' literacy in their daily work and enhance their sense of coordination and arrangement[11]. Production thinking helps transform the backward and wrong production concepts accumulated by employees in the old traditional production thinking, while learning advanced production theories will also make operators consciously think about the direction of improvement in their daily work, thus promoting the development of enterprise production line improvement activities.

5 Conclusion

(1)Analyzing the structure of the product and the process flow, measuring the operating time of each workstation and dividing the operating units, it is concluded that the balance rate of the production line is 71.72% and the production line is in a serious imbalance.

(2)An optimization plan to improve the balance of the motor production line was proposed. The basic industrial engineering method was used to improve the overall production operation of the production line and the work content of some work cells[12]. The balance rate of the production line was increased from 71.72% to 78.23%.

(3)The production effect of the improved production line was analyzed. The improved production line has a better effect than the one before the improvement in terms of the balance rate, which makes the production line reach the scientific management level and provides a reference idea for the improvement of the balance of similar production lines.

(4)By implementing 6S site management, forming 6S management system, cultivating employees to develop the habit of 6S activities and creating a good atmosphere brought by 6S management.

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