Research on Production Line Balance Optimization Based on Lean Production Theory

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Abstract

The imbalance of production lines is a major obstacle to the progress of production. Electronic component manufacturing Enterprise D has serious problems such as accumulated backlog of products, uneven staff and equipment, not smooth production process, and low production line balance rate.The problem of Enterprise D is based on the theory of lean production, using industrial engineering related technical means to analyze and optimize the production line.Analyze the bottleneck process by analyzing the production line of electronic components M.Through optimization, the load between the various processes tends to be averaged, and the waste of waiting for personnel equipment is eliminated, the output fluctuation is reduced, the production efficiency is improved, the production line balance rate is improved, and the competitiveness of the enterprise is enhanced.

Keywords

Lean production, Line balance, Work research, Electronic component processing enterprise.

1. Introduction

In recent years, the industry 4.0 era has accelerated,and "Made in China 2025" also accelerates the industry to move towards mid-to-high-end development.[1] With the rapid popularization and development of electronic equipment and related products, China's electronic component manufacturing enterprises are facing unlimited opportunities.[2]But they also face many problems and challenges.In many electronic component manufacturing enterprises, there are widespread problems of unbalanced production lines such as waiting for work, uneven man-machines, and accumulation of products, which are directly related to production line capacity, production cost, and corporate profits.Enterprise D is an electronic component manufacturer. After continuous development and growth, the products are exported to overseas countries, but similar problems and ills exist in the internal production lines of the company. Balancing the production line is an important way to solve the problem, but in the process of improving the production line, we can't blindly pursue the high balance rate.This study is focused one production line M of enterprise D of low production efficiency, product yield and volatility, man-machine busy uneven idle problems, long production cycle, the production cost is high, the enterprise profit space is little, step by step analysis of the various factors influencing the line balance rate is low, and the use of methods study, work measurement, “5W1H” and “ECRS”to optimize production line.[3]-[6]In order to reduce or eliminate the waste of action and the waste of machine and personnel waiting, reduce production fluctuations, improve production efficiency, and ultimately improve the balance of production lines, thereby enhancing the competitiveness of enterprises.

2. Overview of Production Line M

2.1 Production Status of Production Line M

The production line M is mainly responsible for the production of the model MQ36, which is produced in large quantities.The production line adopts the product principle, that is, the assembly line. It is mainly responsible for the 12 steps: Packing PF Tape, Winding Coil N1, Knotting Coil, Winding Coil N2, Threading sleeve, Taping outside, Finishing, Trimming and pressure line tray of MQ315 products.This production line assigns each process to one or more stations, consisting of 31 stations, each of which corresponds to an operating staff.The current product orders average 100k per month, 20 working hours per month, 8 hours a day, 10 minutes in the morning and afternoon.

2.2 Existing Problems in Production Line M

Since its inception, MQ362 has developed into one of D's main products, and the order volume has gradually increased.The goal of this improvement is to shorten working hours, increase production capacity, increase production line balance rate, and reduce production costs.Through detailed analysis of the production line by means of program analysis, job analysis and motion analysis, the following problems were found.

Production line balance rate still has room for improvement

The time chart of each process before the improvement is shown in Table 1. The Operating Loading Chart of each process line is shown in Fig.1.

Table 1. The initial work schedule each process

Serial Number	Working Procedure	Working Time/s	Free Time/s	Number of People
100-01	Packing PF Tape	2.7	1.96	2
100-02	Winding Coil N1	4.33	0.33	8
100-03	Knotting Coil	3.2	1.46	1
100-04	Packing Tape	3.1	1.56	2
100-05	Packing PF Tape	3.6	1.06	2
100-06	Winding Coil N2	4.66	0	7
100-07	Threading sleeve	3.8	0.86	1
100-08	Knotting Coil	3.6	1.06	1
100-09	Taping outside	3.65	1.01	2
100-10	Finishing	3.85	0.81	2
100-11	Trimming	4.25	0.41	2
100-12	Pressure line tray	4.45	0.21	1
Total		45.19	10.73	31

It can be seen from the current mountain product map that the Process 100-06 is a bottleneck process, and the difference between other processes and the bottleneck process is obvious.When the production requirements are not high, such contradictions may not be obvious. As the output increases, this problem becomes more and more prominent. Some location relative surplus production capacity, leading to equipment idle, due to uneven process beats, especially the bottleneck location clear, make the per capita capacity and overall capacity do not have access to further enhance, must make the whole production line with extended working hours or weekends to make up the lack of capacity.

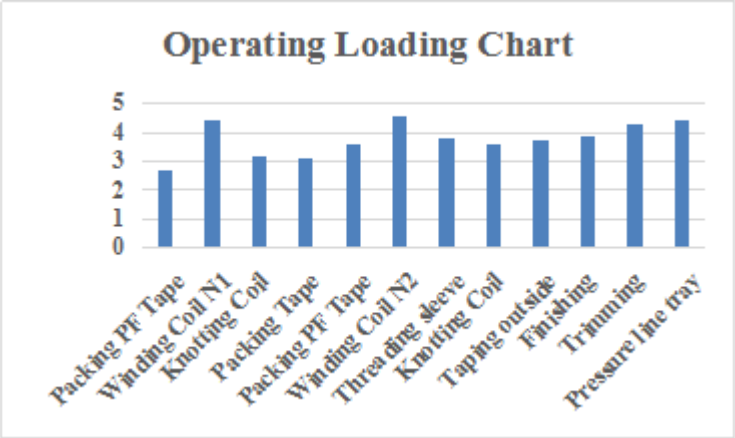

Fig 1. Operating Loading Chart

From Table 1 and the production line balance rate calculation formula, the current balance rate of the production line and the balance loss rate of the production line can be calculated.

The balance of the production line:

$$P = \frac{\text{Sum of each process time}}{\text{Number of operations} \times CT} \times 100\% = \frac{45.19}{12 \times 4.66} = 80.81\% \quad (1)$$

(CT indicates the line beat of the production line (the working hours of the bottleneck process winding N2).

The balance loss rate of the production line:

$$d = \frac{\text{Total time lost by each operations}}{\textit{Number of operations} \times CT} \times 100\% = 1 - P = 19.19\% \quad (2)$$

According to the evaluation criteria of the balance of the production line, referenceTable2 [7]. This result is at the degree of good, but it is close to the edge of the difference, so the production line has a lot of room for improvement.

Table 2. The initial work schedule each process

Production line balance loss Rate	Judging Result
d<=10%	Excellent
10%<d<20%	Good
d>=20%	Poor

b. Excess capacity, low output, and room for reduction in production costs

Production line monthly effective working time=20×460×60=552000s ,CT=4.66s

Monthly production capacity = Monthly effective working time /CT=552000/4.66=118455

Per capita monthly output=Monthly production capacity/Number of people=3822

Because the order quantity is stable within 100k, so there is a problem of overcapacity.

c. Problems in the production line process are shown in Table 3.

3. Balance Improvement of Production Line M

3.1 Production Line Process Improvement Analysis

To improve the production line M, the following objectives should be achieved without increasing or decreasing the cost: a. Reduce labor costs and working hour's costs; b. Eliminate excess capacity and increase per capita production capacity; c. Control the production cycle and try to produce according to the order; d. Improve the balance of the production line.

Analyze using the "5W1H" questioning technique

Table 3. Problem summary table

Working Procedure	Problems
100-02 Winding Coil N1	1. More winding and longer machine rotation time(about 18s) 2. During the rotation of the machine, the operator waits for a serious phenomenon and wastes more time.
100-05 Packing PF Tape	1. The turret tape is used now, and the PF tape on both sides of the coil must be separately wrapped for a long working time. 2. It is too short to arrange two people with a turntable bag, and it is too long to arrange one person.
100-08 Knotting Coil	1. Short time to work with the previous station 2. There is even inertia in the operation of the previous station and knotting, and it is not suitable to separate the work.
100-09 Taping outside	1. Arrange the outsourcing before the thread trimming, which is easy to cause the defect of the thread when the tape is wound. 2. When carrying the tape, you must use the hand to manage the line, resulting in waste of working hours.
100-10 Finishing	1. Time is too short, action is simple 2. Repeated action, no added value

Table 4. Analysis by "5W1H"

Questions	Answers
Is the operation process in the production line necessary, can it be simplified?	Can't be simplified.
Whether there is an inspection process during the operation.	Yes.
Check if it is necessary? Can it be cancelled?	It's necessary and Can't cancel.
Why is there idle time?	Wait for the bottleneck process.
Can we eliminate the in-process inventory?	Yes.
How to eliminate inventory in process?	Optimization bottleneck process.
Is the handling process necessary during the production process?	Yes.
Can shorten the handling distance?	The internal handling of the workshop is completed by the conveyor, and the possibility of shortening is small.

Improved with the "ECRS".

Table 5. Analysis by "ECRS"

Questions	Answers
Is there an operation that	Yes.100-11,100-12.The process time is too short, the action is simple, the action is repeated, and there is no added value, so it can be canceled.

can be cancelled?	
Are there any processes that can be combined?	Yes. The process time of 100-11 is too short, the action is simple, the action is repeated, but it is indispensable, and the process time of 100-08 is short, so the merger
Is there a process that needs to be rearranged?	Yes. In the process of 100-02, the number of winding of the machine is large, the rotation time is long, and the waiting phenomenon of the personnel is serious. Now it is changed to a machine with two sets of spools, and the person uses the time of the machine to rotate the sleeve of the tail of the previous product and the sleeve of the next product thread. In the 100-11 trimming process, the trimming line is arranged at the end. When the N1 is wound, the outer wrapping tape and the N2 winding are liable to cause defective products to be caught in the thread. Now the wire ends of the two winding are separated and trimmed, without adding personnel, but the action is broken down into two stations, and the trimming process is carried out before the tape wrapping process. The crimping process was cancelled in the 100-12 press line tray process, and the 200-01 tin plating process was moved to the 100-12 press line tray, which effectively controlled factors such as excessive placement time, transportation and enameled wire bounce. The resulting knot is not good.
Is there a process that can be simplified?	Yes. The 100-05 turntable tape was changed to the machine bag, and the two sets of PF tape were wrapped once and changed to one person.

According to the analysis, the improvement measures for the production line are summarized in Table 6.

Table 6. Improvement measures

Working Procedure	Measures
100-02 Winding Coil N1	1. The habit of using an axis for the previous winding was changed to two sets of spools for one machine. 2. The operator uses the time the machine is rotated to insert the sleeve at the end of the previous product and the sleeve of the next product line.
100-05 Packing PF Tape	1. Change the turntable bag to the machine bag, and the two sets of PF tape are wrapped at one time. 2. Change to one-person work.
100-08 Knotting Coil	1. Incorporating 100-07 into 100-08. 2. Incorporating 100-09into 100-08.
100-10 Finishing	1. Time is too short, action is simple 2. Repeated action, no added value
100-11 Trimming	1. The wire ends of the two winding are separated and trimmed, without adding personnel, but the action is decomposed into two stations. 2. This process is advanced to the 100-09 process
100-12 Pressure line tray	Cancel

3.2 Improved Performance Evaluation

Through the analysis and improvement of the production line M, we can find that the improved process is more scientific and reasonable, and the improved production line schedule is shown in Table 7.

Table 7. The improved production line schedule

Serial Number	Working Procedure	Working Time/s	Free Time/s	Number of People
100-01	Packing PF Tape	5.36	0.14	1

100-02	Winding Coil N1	5.06	0.44	5
100-03	Knotting Coil	4.85	0.65	1
100-04	Trimming	4.89	0.61	1
100-05	Taping outside	5.5	1.06	2
100-06	Packing PF Tape	5.24	0	7
100-07	Winding Coil N2	5.07	0.86	1
100-08	Threading sleeve, Knotting Coil	4.95	0.55	2
100-09	Trimming	4.97	0.53	1
100-10	Taping outside	5.32	0.18	1
100-11	Tin plating Plaque	4.8	0.7	1
Total		56.01	4.49	21

The specific improvement effects are as follows:

a. The labor costs have reduced.

By simplifying the process, four workers were reduced, and six workers were reduced through the rearrangement process, a total of 10 people were reduced, labor costs were reduced, and work efficiency was improved.

b. The working time costs have reduced.

Total working time before improvement=4.66×31=144.46s;

Total working time after improvement=5.5×51=115.50s;

Reduced total working time=144.46−115.50=28.96s.

According to the standard salary of ¥10 / h and the current order of 100k per month, the monthly cost savings can be improved after the improvement: 28.96× 100000÷3600×10= 8045

c. Eliminated excess capacity and increased per capita capacity.

$$\text{Monthly capacity} = \frac{\text{Monthly effective working time}}{\text{CT}} = \frac{552000}{5.50} = 100364 \tag{3}$$

$$\text{Per capita monthly output} = \frac{\text{Monthly capacity}}{\text{Number of people}} = \frac{100364}{21} = 4780 \tag{4}$$

$$\text{Eliminate excess capacity} = 118455 - 100364 = 18091 \tag{5}$$

$$\text{Per capita monthly production increase} = 4780 - 3822 = 958 \tag{6}$$

d. Line balance has increased.

From Table 7 and the production line balance rate calculation formula, the current balance rate of the production line and the balance loss rate of the production line can be calculated.

$$P = \frac{\text{Sum of each process time}}{\text{Number of operations} \times \text{CT}} \times 100\% = \frac{56.01}{11 \times 5.5} = 92.58\% \tag{7}$$

$$d = 1 - P = 7.42\% \tag{8}$$

Referring to the evaluation criteria of the balance effect of the production line, it can be seen that the current production line status level is excellent. The improved Operating Loading is shown in Fig. 2. The balance of the production line balance before and after improvement is shown in Fig.3.

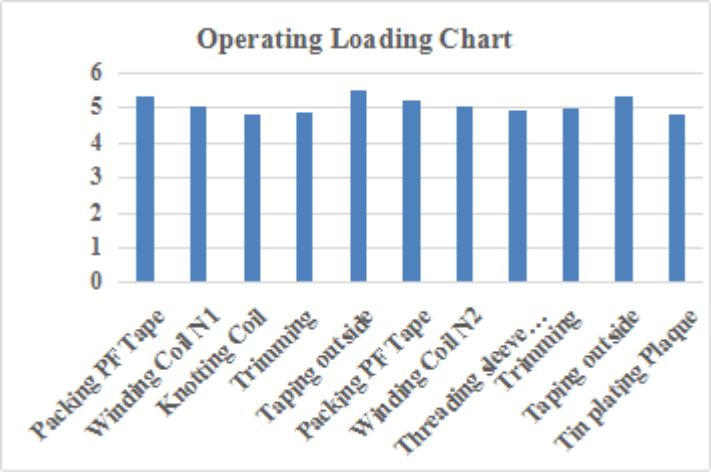

Fig 2. The improved Operating Loading Chart

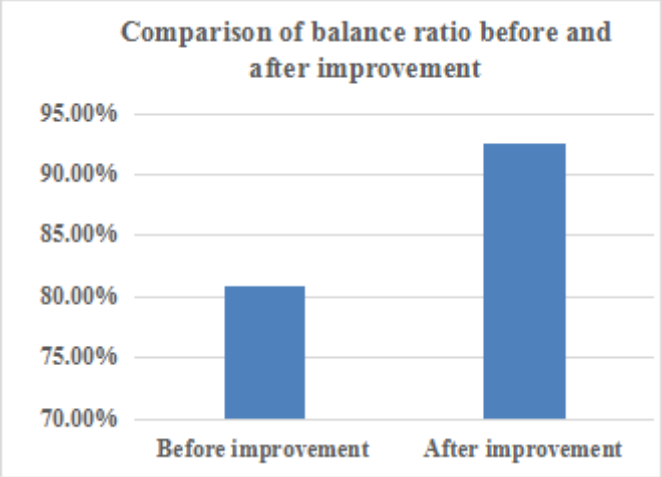

Fig 3. Comparison of balance ratio before and after improvement

4. Conclusion

According to the actual information collected during the internship of D company, the M-production line is optimized and improved by focusing on the application of research methods and related theory and technology of production line balance. First analyzed the status quo of production line, and find out the various factors influencing the production line balancing rate and analyzed, by using the 5 w1h and ECRS to improve analysis, eventually make the whole production process is simple, rationalization, reduced working hours and human waste, improve the production line balance rate.

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