Optimization of Automotive Wire Harness Production Process Based on Lean Manufacturing

Wenjing Liu[1,a*], Shichang Lu[1,b]

2421367830@qq.com[a*], lushichang@126.com[b]

School of Business Administration, Liaoning Technical University, Longwan South Street, Huludao City, China[1]

Abstract: In order to solve the problems of long working hours, complex workflow, and long turnaround time, we applied the lean production concept to the assembly line of our main product, A9815086 automotive wiring harness. The IE method was used to analyze and optimize the production process of the automotive wiring harness assembly(Yi 2006), and the workstations were re-combined according to the ECRS concept to eliminate unnecessary waiting time; the equipment was adjusted nearby to reduce the handling distance so that the number of unbalanced stacking work stations for semi-finished product production was reduced by 50%, the frequency of process turnaround handling was reduced by 42%, and the handling distance was reduced by 32%; the operating time of each production process was measured, and the original process content was adjusted according to the principle of production line balance(Guo 2020). The operating time of each production process was measured, and the original process content was adjusted according to the principle of production line balance, and the production line balance rate was increased from 69.29% to 91.47%, which significantly improved the economic efficiency of the enterprise.

Keywords: lean manufacturing; Automotive wiring harness assembly; Assembly line balance rate; Layout optimization

1 INTRODUCTION

As new energy vehicles entered a period of growth, the automotive wiring harness industry is also developing. At present, the automotive wiring harness market is highly concentrated, with more than half of the world's products made in Japan. Although there are more domestic automotive wiring harness manufacturers, most of them are small in scale, with weak R&D capabilities, backward production equipment, long production cycles, and poor production flexibility. In order to survive and develop better in the fierce automotive wiring harness market [7], it is the best choice to improve productivity and eliminate waste through the lean production concept.

The essence of lean production is a production method that uses modern management methods, takes human motivation as the core, allocates and utilizes enterprise resources effectively, and aims to completely eliminate ineffective labor and waste to maximize the economic benefits for the enterprise[1]. By continuously reducing costs, improving quality, enhancing production flexibility, and eliminating defects and waste in every post on time, the enterprise has a greater production space and competitive advantage.

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Improving the production process can reduce stagnation and wait, avoid wasting large amounts of human and material resources, and effectively increase labor productivity. At the same time, it can reduce a lot of handling, and movement and make the logistics smooth, thus directly or indirectly improving productivity[4].

This paper discusses the assembly line of the company's product A9815086 automotive wiring harness. Through on-site inspection of the existing process, production flow, and operation methods, we analyze and improve the economic factors such as unreasonable operation movements and process arrangements by applying the ECRS concept to develop a more reasonable process structure and standard work methods, as well as re-plan and design the production plant layout to reduce handling [6]. We also re-plan and design the layout of the production hall to reduce wastefulness and achieve higher production efficiency.

2 Analysis of the current state of production

In recent years, in the production process of the company's automotive wiring harness products, there are problems such as long product working hours, complex product workflow, segmented operations, frequent in-production turnaround, and long turnaround time, which make the enterprise's economic benefits fail to meet expectations. To this end, after understanding the logistics as well as information flow between each process in the product production process, a production area map as shown in Figure 1, and a production line balance rate table as shown in Table 1 were drawn for clarifying the production time and value-added time of each production unit of the product, and then analyzing the production bottleneck points by combining the relevant data[9].

Table 1. Production balance rate table.

Project	Job name	Number of operators	Standard time	Total Work	Line Balancing Rate
Cutting harness	Cutting harness	2	1210	605	/
1	Organize & Trim harness	1	130	717	85.36%
	Stripped core wire	1	120		
	Rivet end 1	1	168		
	Rivet end 2~6	1	150		
	Terminal Inspection & Solder Baking & Soldering	1	149		
2	Solder joint inspection & Testing & Assembly of parts	1	149	477	80.03%
	Threading plugs 1-3	1	108		
	Tin dipping process 2	1	120		
	Welding	1	100		
3	Ultrasonic conductor fusion 1	1	1050	5229	49.80%
	Piercing heat shrinking tube 2	2	720		
	Threading Sleeve & Woven Mesh 1	6	3582		
	Solder dipping 3 & Solder 3 & Solder joint inspection	1	75		
4	Assembling HSG & Assembling	1	93	510	85.00%

	injection parts 1				
	Assembling HSG & Assembling injection parts 2~4	1	100		
	Assembling HSG & Assembling injection parts 5~7	1	120		
	Assembling HSG & Assembling injection parts 8	1	110		
	Assembling HSG & Assembling injection parts 9~11	1	87		
5	Fixed woven wire mesh 1	2	936	1866	66.45%
	Rivet end 7 & Terminal inspection & Grouping HSG 2	1	50		
	Electrical test 2	1	160		
	Baking heat shrink tube 1	2	720		
6	Labeling 1	1	188	1424	49.10%
	Electrical test 3	1	160		
	Assembled parts 2 & Electrical test 4	1	180		
	Size and appearance inspection 1	1	580		
	Labelling & Bagging & Packaging	1	130		
Total		35	11, 445	Balance rate	69.29%

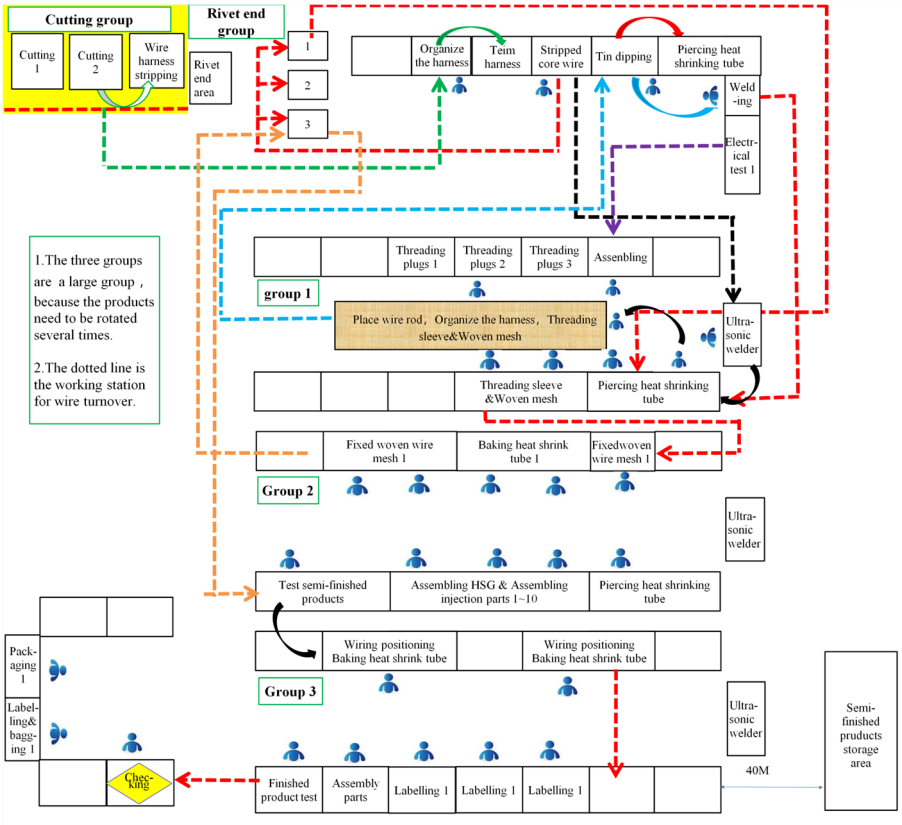


Figure 1. The operation site before improvement.

Through production area map analysis, interview observation, and production line balance rate statistics, we found that the company has the following main problems in the automotive wiring harness assembly operation.

2.1 The process layout is not reasonable

As shown in Figure 1, the production of this material number requires a total of 58 production processes: in addition to the wire-cutting station, it is divided into 6 cycle operation sections, requiring 35 employees, each batch of work orders according to 200PCS operation, the actual cycle operation by 13 employees. Because the production of the automotive wiring harness is a batch operation, each workstation has repeated pick and place action, that is, the production line winding and then spread out, each product waste about 1500 seconds; the production line operation area is too large, personnel scattered, staff work action is not clear resulting in a waste of time about 1000S/PC; each cycle need to carry the product to the staging area, a straight line distance of 40m, six cycles about 24 times to carry, and then the product from the staging area to pull The total handling time is 48 times, and each handling time is 3 minutes, so the total wasted handling time is 8640 seconds. The unreasonable layout of the process leads to a serious waste of resources and low production efficiency of the enterprise.

2.2 Low balance rate of the production line

Line balance ratio = sum of station time / (bottleneck process time * the number of processes). The production efficiency of the production line is determined by the bottleneck process time, and the longer the bottleneck process time [8], the lower the efficiency. By analyzing Table 1, it can be seen that the highest balance rate of production in 6 sections of operation is 85%, the lowest is 49%, and the overall balance rate is 69.29%, of which about 2775s are caused by handling, pick-and-place action, and unclear work combined, and the standard work time is 11,445s. The bottleneck process seriously restricts the balance of the production line, resulting in low PPH and high production loss rate.

3 Improvement measures and implementation

3.1 ECRS-based production process optimization

ECRS is a set of four principles in industrial engineering, namely Eliminate, Combine, Rearrange, and Simplify, which are used to optimize process formulation and achieve higher productivity [11]. In this paper, we use ECRS to analyze and optimize the production process, and after merging and dividing some processes [2], the optimized production process is reduced from the original work sequence (Tables 2, 3), saving assembly time, reducing workers' labor intensity, and significantly improving production efficiency [5].

Table 2. Improvement table for auxiliary plugging jig.

Problem/Status Analysis: (1) The original process employees use manual work. 2）Each time the employee puts on the plug, he/she needs to press it once.	Before improvement:

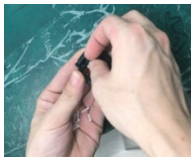
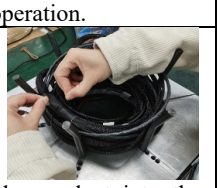
3) Employees need to confirm the pin position before and after putting on the plugs. (4) Before the improvement, the work time of this picking and assembling action was 84.0 seconds/PCS.	  The employee keeps one hand on the HSG and after confirming the pin position, the other hand threads the plugs one by one and presses.
Improvement principle: □E ■C □R ■S	
Improved focus: (1) Now use the jig to help employees work with both hands. (2) Employees do not need to confirm the pin position before and after the work, the jig has already opened the pin position hole, just plug the plug into the hole. 3）Replacement of multiple press plugs with a single press of the jig.	After improvement:   Fix the HSG in the fixture, fill the plug on the open pin position hole, and press it at once.
Improvement effect: Original time:84 seconds. Improved: 52 seconds, saving 32 seconds. Improvement benefit: 38% efficiency gain.	
Improvement effect: Original time:78 seconds. After improvement: 30 seconds, saving 48 seconds. Improvement benefit: 61.5% efficiency gain.	

Table 3. Improvement table for wire tying jigs.

Problem/Status Analysis: 1）Winding machine is used to wind the products when packing 2）After winding the wire, one person should fix the product not to spread, and another person should tie the mini-band.	Before improvement:   One employee needs to fix the product after winding, and another employee needs to tie the mini-band operation.
Improvement principle: □E ■C □R ■S	
Improved focus: 1) Design and make a fixed product jig to fix the product and avoid the product from spreading after winding, to facilitate the operation.	 
Improvement effect: Original time:150 seconds. After improvement: 110 seconds, saving 40s. Improvement benefit: 26% efficiency gain.	After winding, put the product into the fixing fixture and then do the mini-banding operation to reduce one person fixing the wire.

3.2 Production equipment/installation improvement

The original hanging wire car structure is simple, and low height, in the use of the process there are products piling pressure to pick up not easy, handling frequency, picking up the operation action is not convenient, a single group of wire from the wireframe trouble, operating range and other problems. The first is to improve the height of the equipment and workbench by elevation, so that the same height of the equipment and workbench, are easy to pick up; the second is to change the placement method, increase the number of placements to avoid product stacking, to eliminate the risk of bad caused by product stacking; third is to increase the design of the pulley and height difference, by the gravity of the product to slide to the work position, the turnover of temporary storage frequency reduced by 3 times, the handling distance shortened 676M, reducing 32.37%.

3.3 Job site improvement

First, adjusting the riveting end to in-line streamlined production, realizing one-person, multi-machine operation; reducing turnover by re-combining operational workstations.

Secondly, the equipment is adjusted in proximity to reduce the handling distance and improve production efficiency; thirdly, the work tools are assisted to improve and the workstations are combined and reorganized to reduce the turnover. The improved production situation is shown in Figure 2.

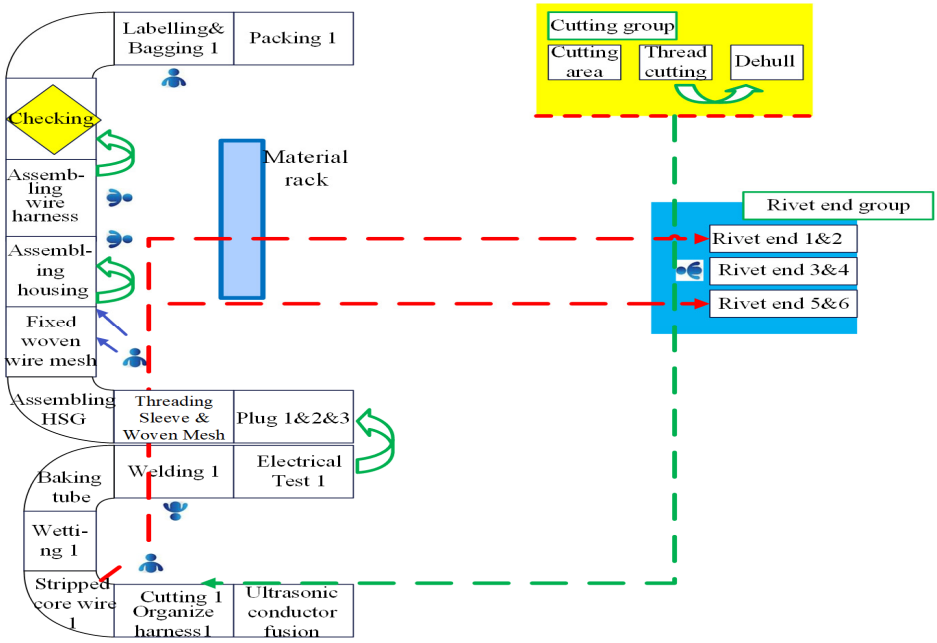


Figure 2. The operation site diagram after improvement.

4 Effectiveness evaluation

4.1 Comparison of operating hours

Through the improvement of the production process, the time spent between each process is closed and the production line is more balanced. The improved operating time and the number of workers are shown in Table.

Table 4. The number of operators and time after improvement.

Name	Work-stations number	Job Name	Number of workers	After impro-veme-nt
Cutting Line	1~5	Cutting1 ~ Dehull 1	1	1210
Terminal riveting	6~12	Rivet end 1~Terminalinspec tion	1	370
Assembly Harness	13~24	Rational line 1~ Piercing tube 3	1	690
	25~29	Tin dipping process & Baking heat shrink tube 2	1	664
Cabling & Finishing	30~34	Wearing sleeve & woven mesh 1~ Baking heat shrink tube 1	1	974
	35~57	Sleeving & Woven Mesh ~ Electrical Tet 4	2	3578
	58~60	Checking~ Packing	0	610
Total			7	8096

4.2 Production balance rate after line improvement

Substituting the improved data into the equation of production line balancing, we get the wire assembly balancing rate of 98.12%, wiring, and finished product balancing rate of 84.41%, and total balancing rate of 91.47%, which is 22.18% higher than the production line balancing rate of 69.29% before the improvement.

4.3 Benefit comparison

After the improvement of the production process, the number of employees was reduced from 13 to 7, which reduced the human resources required by 46.17%; the work standard was changed from 11.445 seconds to 8096 seconds, which reduced by 43.07%; the overall area of the production area was changed from 163.8m2 to 63.61m2, which reduced by 63.61%.

5 Conclusion

(1) Lean manufacturing method and IE method were used to analyze the operation flow of the assembly line of the company's product A9815086 automotive wiring harness, and the operation

time of each workstation was tested in the field to identify the bottleneck processes affecting the whole production line.

(2) The original production process was optimized by applying ECRS principles, eliminating, merging, adjusting, and simplifying the work content of each station, reducing unnecessary waiting time, and modifying the layout of the production line. The improved production process required 6 fewer employees, and the overall area of the improved production area was reduced to 63.61m2. The production line balance rate increased from 69.29% to 91.47%, resulting in significant economic benefits.

(3) The research contents and analysis methods of this paper have certain reference significance for the improvement of other product lines and the optimization of production processes of the company.

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