Application of Work Study to the Improvement of PCB-Assembly Line

Xin-xin Han and Xu-hong Guo

Abstract The circuit board final assembly process is discussed as an application example in this study. In order to find the bottleneck stations where the production efficiency are low, work measurement is employed to determine operation time of every station. The paper applies analytical methods of process, operation and movement of work study to analyze the assembly line. Then the technique of 5W1H, ECRS and economic principle of motion is applied to improve the bottleneck. Through good results in comparison with the old scheme, the balance rate is increased and the product efficiency is enhanced.

Keywords Balance rate • Method study • Work measurement • Work study

1 Introduction

Work study includes method study and work measurement [1]. As the core and foundation of the industrial engineering, work study has always been paid high attention. This paper applies the methods of work study to the circuit board final assembly line of a certain electronic enterprise with a series of analysis and improvements. Firstly, in order to find the bottleneck stations and calculate the balance rate, work measurement is employed to determine operation time of every station. And then the paper applies analytical methods of process, operation and movement of work study to analyze the assembly line. With the purpose of solving the problem of low balance rate and product efficiency, the technique of 5W1H, ECRS and economic principle of motion is applied to improve the bottlenecks. In this paper, the method has enlightening and practical value for similar enterprises.

X. Han (✉) • X. Guo
School of Mechanical and Electric Engineering, Soochow University, Suzhou 215006, China
e-mail: xinxinhan_ruth@163.com

E. Qi et al. (eds.), *Proceedings of 2013 4th International Asia Conference on Industrial Engineering and Management Innovation (IEMI2013)*,
DOI 10.1007/978-3-642-40060-5_9,

2 Work Status and Problem Analysis

2.1 Work Status

Due to the increase in customer demands, electronic products of a certain enterprise are in short supply. And only when the production cycle of the products goes down to 11 s or below that, the production satisfies market beat need. The production procedure is distributed into the front-end process and back-end process. The front-end process is surface-mount technology (SMT), and it is production cycle has been lower than 11 s. The back-end process is the circuit board final assembly. Because it is not long until the production line is set up, it is production efficiency is low. In order to achieve the goal of the 11 s, we must take measures to improve the assembly line.

For PCB-Assembly Line, the processing craft route is from outer processing to the assembly with PCB, and eventually to the lid assembly, etc. Before improving, the assembly flow process is shown in Table 1 [2]. Need to explain, manual, machine and manual-machine operation time of every station is measured with Methods Time Measurement (MTM) which belongs to work measurement technique and these data is added wide release rate (2 %) [3]. According to the data from Table 1, the operation time histogram for each station is shown in Fig. 1.

2.2 Problem Analysis

As the Fig. 1 shows, the longest operation time of the production line is in station 10, and the operation time of 19.67 s is the production cycle of the production line. To calculate the balance rate, the computational formula [4] is: the total of operation time/(the longest operating time * number of workstations) * 100 % = 278.2/(19.67 * 22) * 100 % = 64 %. Under normal circumstances, when the production balance rate is between 60 and 70 %, there are the factors that people consciously balance the production line. But some deep-seated problems still are not resolved [5]. On the basis of above conclusions, it is clear that this enterprise has not carried out in-depth management activities on the assembly line. As a matter of fact, most of the operation time is higher than the target.

In order to improve the production efficiency and meet the demand of market, it is necessary to improve the whole production line. The paper uses the analysis tools of 5W1H combined with the economic principle of motion to find points which need improving. According to the actual situation, the following problems are found in the original assembly line:

1. The flow process is unreasonable; there are unnecessary operations.
2. Waste of one-handed operation exists.
3. Some operations do not conform to the economic principle of motion.

Table 1 The original flow process chart

Station No. [8]	Event description	Distance (m)	Operator amount	Time (s)			Symbols [9]				
				Manual	Machine	Manual-machine	○	□	→	◘	▽
1	Laser engraved code and dispensing		1	4.2	8.0		○				
2	UV glue drying		1	9.1	4.5		○				
3	Welding		1	8.5	3.8		○				
4	Buffer ball assembly		1	4.4	7.0	3.0	○				
5	Air leak test		1	10.4	9.0	4.0		□			
6	Weld visual inspection		1	6.1				□			
7	Coil 1 pre-install manually		1	15.3			○				
8	Coil 2 pre-install manually		1	13.8			○				
9	Coil 3 pre-install manually		1	13.8			○				
10	Coil 4 pre-install manually		1	17.5	2.5	0.3	○				
11	Press-in coil		1	4.9	10.7	4.9	○				
12	Spring 1 assembly		1	10.5	4.4		○				
13	Spring 2 assembly		1	8.5	2.0		○				
14	Pin position examination		1	8.2	5.0			□			
	Move to the next station	2.4	1	1.8					→		
	Take outer and PCB	2	1	2.0					→		
15	Press-in PCB		2	11.8	12.0	11.8	○				
16	PCB visual inspection		2	10.2				□			
17	Laser welding the lid		1	9.9	11.8	9.9	○				
	Move to the scan station	4.6	1	4.3					→		
18	High temperature furnace		1		11.0		○				
	Put in the test station	2.8	1	3.0					→		
19	High temperature test		1	12.4	14.9	12.4		□			
	Put in cooling furnace	2	1	3.0					→		
20	Cooling furnace		1		11.0		○				
21	Sealing ring assembly		1	13.7	3.0		○				
	Functional test		1		6.1			□			
22	Final inspection and packing		2	10.7						◘	

4. The sequence arrangement of man-machine operations is not reasonable so that the utilization rate of men and machines are very low.

3 Improvement in the Assembly Line

To solve above problems, the technique of 5W1H, ECRS and economic principle of motion is used to improve the assembly line [6].

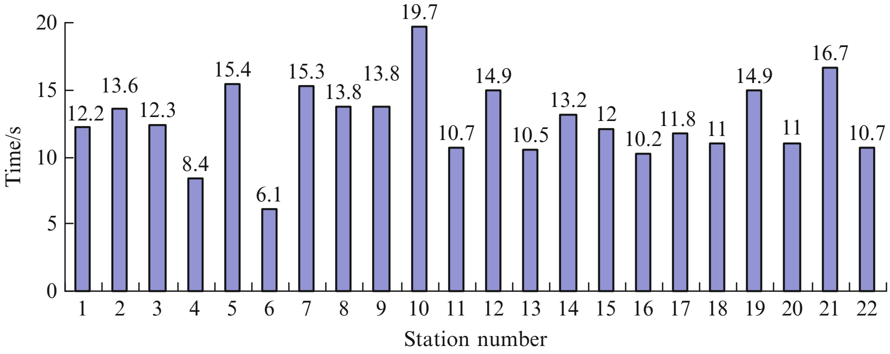

Fig. 1 The former operation time of every station

3.1 Improvement in the Flow Process [7]

1. Cancel the process "Weld visual inspection". The process "Air leak test" is used to check whether welding points leak. In order to guarantee quality, the process "Weld visual inspection" is set to check again whether welding points leak. But in the actual production, nonconforming rate of visual inspection is almost zero, so the process "Weld visual inspection" is unnecessary operation and can be cancelled.
2. Merge some processes. You can see from Fig. 1, there are both no man – machine synchronous operations in "Laser engraved code and dispensing" (process 1) and "UV glue drying" (process 2). When the operator of process 1 is working, the machine has 4.3 s leisure time. And when the machine is working, the operator has 8 s waiting time. On the contrary, the leisure time of machine is 9.1 s and the waiting time of operator is 4.5 s in process 2. The two processes can be merged so that one operator can operate two machines at the same time. By the same token, "Buffer ball assembly" (process 4) and "Air leak test" (process 5)can be merged, merging "Press-in coil" (process 11) and "Spring 1 assembly" (process 12), merging "Pin position examination" (process 14) and "Press-in PCB" (process 15).

3.2 Improvement in Operations

3.2.1 Operations with Both Hands [10]

Waste of one-handed operation exists in "Welding" (process 3) and "Sealing ring assembly" (process 21).

1. The original way of process 3 follows: The left hand stretches into outer boxes waiting for the processing, picks up one of them, moves into the fixed handle

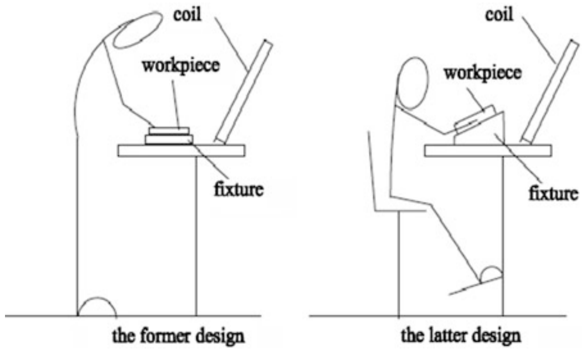

Fig. 2 The former and latter motions

belonging to machine fixture and keeps fixed. Then the right hand with the suction pen reaches into welding points of outer boxes, puts down the sealing fin and exits the work area when the left hand presses the start button. After pressing the button, the machine starts welding. Improved methods: A rubber band which can fix the suction pen on the hand is designed. And the sealing fin can be sucked through the fingers moving the suction pen. Because the pen is small in size, the hand with suction pen can pick up outer box at the same time. To operate easily, the fixed handle can be extended to outside work area.

2. Process 21 exists the following problem: To prevent o-rings falling into other workspaces, the left hand need hold the clamp handle when o-rings are inserted. Improved method: An equipment placing o-rings is designed. With o-rings inside the handle, slide the button to insert o-rings into the fixture, and the funnel which size is greater than 25 mm in diameter can prevent o-rings falling into other workspaces.

3.2.2 Motions Analysis [11]

1. Coil pre-install manually (process 7–process 10) has similar basic motions and is part of meticulous assembly work. The distance between working surface and eyes is too long, causing the operator need bow and lower his head to insert and raise his head to get the coil. From the perspective of human factors engineering, motions are not reasonable. Using economic principle of motion to improve: Considering that the position is fixed and operators does not need to walk, so the four processes can be set to the sitting position and the distance from eyes to working surface is about equal to 40 cm. It is convenient for operators to work. Before and after improvement, the status is given in Fig. 2.
2. Spring 1 assembly (process 12) is used to lift the pneumatic spring into four holes for assembling. As a result, motions include positioning for four times, inserting for four times and separate operation for four times. And the left hand has always been idle. Three screwdrivers are increased into the equipment and four screwdrivers are fixed side by side, and spacing interval is equal to that of

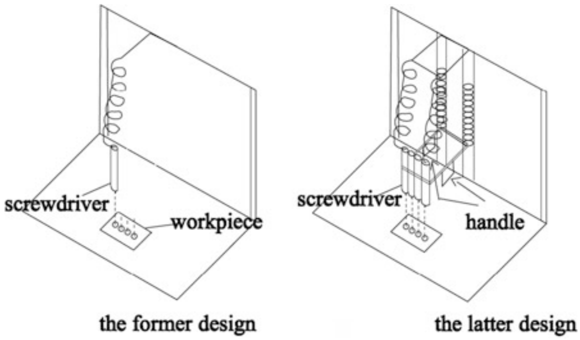

Fig. 3 The former and latter devices

four holes in outer boxes. To reduce weight of screwdrivers, they are fixed with the fixture in 30 cm above four holes. When need to assembly, just hands pull hand lever, complete loosen the hand lever assembly, automatic rising whorls. The former and latter devices are shown in Fig. 3.

3. The process “Press-in PCB” (process 15) whose main job is assembling outer box and PCB and whose operation time is longer, needs improving with economic principle of motion. The manipulator can be split into two parts of input and output. On the left side, the manipulator transport PCB and outer box into machines for processing. On the right, manufactured assembly is inputted with another manipulator. Through improving the layout and machine in itself, the distance is shortened and the utilization of operators and machines.

3.2.3 Manual-Machine Operation Analysis [12]

The original operation of “High temperature test” (process 19) is that: The operator demounts the assembly which has been tested from machine1, puts it into the cooling furnace, takes other assembly to be tested from high temperature furnace, assembles it with machine1, presses the button and machine1 starts testing. Then the operator moves to machine2 for the same work. When one operator operates two machines at the same time, the waiting time and leisure time is longer and the arrangement of manual-machine operation is unreasonable. The improving way is that: Don’t need to add equipments and tools, rearrange the operation order and try to use machine working time for manual operation.

3.3 Results Analysis

After the above analysis, Table 2 shows the improved assembly process, and Fig. 4 shows the improved operation time histogram for each station. The balance rate = the total of operation time/(the longest operating time * number of workstations) * 100 % = 181.5/(11.0 * 17) * 100 % = 97 %.

Table 2 The latter flow process chart

Station No.	Event description	Distance (m)	Operator amount	Time (s) Manual	Machine	Manual-machine	Symbols ○	□	→	□○	▽
1	Engraved code, dispensing, glue drying		1	10.0	8.0	8.0	○				
2	Welding		1	10.8	3.8	3.8	○				
3	Buffer ball assembly, air leak test		1	10.9	9.0	9.0				□○	
4	Coil 1 pre-install manually		1	10.5			○				
5	Coil 2 pre-install manually		1	10.5			○				
6	Coil 3 pre-install manually		1	10.5			○				
7	Coil 4 pre-install manually		1	10.5			○				
8	Press-in coil, spring 1 assembly		1	10.8	10.7	10.7	○				
9	Spring 2 assembly		1	10.7			○				
10	Pin position examination Press-in PCB		1	10.9	8.0	8.0				□○	
11	PCB visual inspection		2	10.2				□			
12	Laser welding the lid		2	9.4	11.0	9.4	○				
	Move to the scan station	4.6	1	4.3					→		
13	High temperature furnace		1		11.0		○				
	Put in the test station	2.8	1	3.0					→		
14	High temperature test		1	9.2	11.0	9.2		□			
	Put in cooling furnace	2	1	3.0					→		
15	Cooling furnace		1		11.0		○				
16	Sealing ring assembly		1	10.5			○				
	Functional test		1		6.1			□			
17	Final inspection and packing		2	10.7						□○	

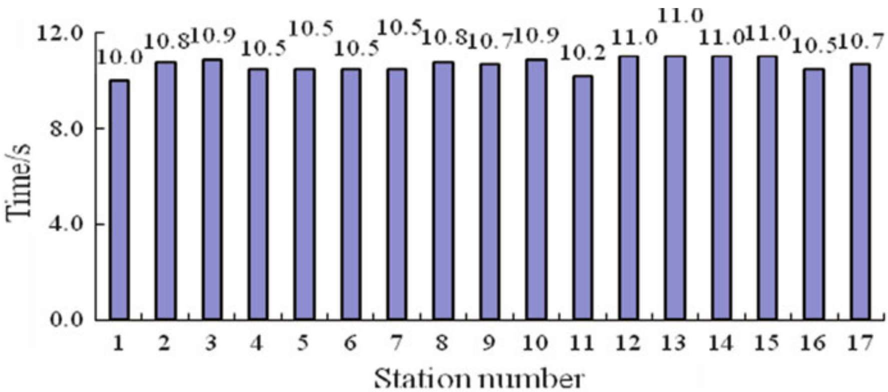

Fig. 4 The latter operation time of every station

Table 3 The contrastive parameters

	No./operator	Distance	Station	Cycle time	Total time	Balance rate
Before	23	13.8 m	22	19.7 s	278.2 s	64 %
After	17	9.4 m	21	11 s	181.5 s	97 %
Effect	6 operators less	4.4 m less	1procee less	8.7 s less	96.7 s less	33 % higher

4 Contrastive Analysis

After the above adjustments and improvement, the following results have been achieved.

In the case of guaranteeing quality, the process is more scientific and reasonable [13]; the labor cost is greatly reduced. Through designing and improving devices, operators make full use of the hands to finish works and have more reasonable and easier operational motions, which make labor intensity of operators reduce and production efficiency enhance greatly [14].

In order to clearly show that improvements, the summary of comparison results in original and latter parameters is given in Table 3 [15].

5 Conclusion

This paper applies the theory and method of work study to the practice of PCB-Assembly line in a certain electronic enterprise. With the minimal or no input, bottleneck stations are solved and the balance rate is increased through the process and operation optimization. The most important thing is that production cycle time achieves the enterprise goal and meets the market needs.

References

1. Yi Shuping, Guo Fu (2007) Fundament of industrial engineering (in Chinese). China Machine Press, Beijing
2. Zhang Zhiqiang, Zhou Binghai (2007) Improvement of car-seat assembly line based on process analysis (in Chinese). Machinery 45(10):56–59
3. Guo Fu, Li Sen (2003) Research on problems in application of work measurement technology (in Chinese). Ind Eng J 6(3):57–60
4. Li Qin, Li Ze-rong, Qing Xin-yu, Wen Zhong-bo (2011) Application of work study on the improvement of assembly production line (in Chinese). Mod Manuf Eng 35(6):93–96
5. Sun Jian-hua, Gao Guang-zhang, Jiang Zhi-qiang, Shi Jin-fa (2005) The application of program analysis method in streamline balance (in Chinese). Mach Des Manuf 51(5):148–150
6. Wang Haiyao (2011) Application of work-study to assembly line of automotive dashboard module (in Chinese). Manuf Technol Mach Tool 63(11):50–53

7. Lan Shuang, Li Dan-ring (2010) Application of work study to the redesign of a stator assembly line (in Chinese). Ind Eng J 13(3):126–129
8. Liu Yang, Wang Jun, Zhang Shuntang (2012) Analysis and optimization design of production system for GE Company (in Chinese). Value Eng 31(30):17–18
9. Wu Aihua, Wu Meilei (2007) A study on flow process analysis system based on MES in discrete manufacturing. In: The 14th international conference on industrial engineering and engineering management, Shandong
10. Jin Jun, Wu Xiong (2013) Application of work study in the component of massage chair assembly line balancing (in Chinese). Value Eng 32(2):296–298
11. He Xiangzhu (2008) Application of work study to the work improvement of Ti—assembly line (in Chinese). Ind Eng Manag 13(4):102–105
12. Wu Aihua, Yin Fupeng (2009) Research on operation process analysis system based on MPM platform. IEEE Press, Beijing, pp 468–471
13. Zhao Xiu-xu, Zhao Hui-zhen, Wang Min, Wang Xiao-guang (2008) The application of a process analysis and improvement method to router production process (in Chinese). Ind Eng Manag 13(3):116–120
14. Liu Xiaohui, Xu Zhipei, Xue Shun, Cui Ping, Hong Hao (2012) The application of work study in the production site management of one enterprise (in Chinese). Mod Manuf Eng 35(2):57–60
15. Cheng Xiao-juan, Zeng De-fu, Quang Chun-guang (2010) The application of work-study in the efficiency improvement of laptop test line (in Chinese). Ind Eng Manag 15(1):121–125