Production Process Improvement based on Work Study

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***Abstract* — Aiming at the problem of some laptop battery, such as low balance rate of the assembly production line, unreasonable station layout, etc., this paper adopts the work study to make analysis and improvement. Firstly, apply the work measurement technique to measure the operation time of each station, and identify the bottle-neck stations; then, apply "5W1H" questioning technique and "ECRS" principles to make improvement and re-arrange the production line. Through the improvement, enhance the balance rate of the production line, optimize the plane layout, balance the work of each stations, simplify the personnel, and reduce the unnecessary waiting; reach the goal of reducing the cost and improving the production efficiency.**

Keywords - work research; balance of production line; production process; improvement

I. INTRODUCTION

The work study is the core and basis of the industrial engineering, which is also named as basic IE, including two major techniques, i.e. method study and work measurement [1-2]. The method study is focused on seeking the economic and efficient work method. The work measurement is to confirm the scientific and reasonable working hour norm of each operation. Its obvious characteristic is that, with only small investment or without the investment, through the improvement of the work flow and operation method, carry out the advanced and reasonable work quota, make full use of the enterprise resources, develop its internal potential, improve the production efficiency and benefit, reduce the cost and enhance the enterprise competition ability. At present, the work study method has been widely applied in Chinese enterprises. Apply the work study method to analyze the production process of some factory, mainly aiming at the analysis and improvement design of the man-machine operation [3]. Aiming at the low production efficiency of the stator assembly and production of some motor maker, apply the work study method to analyze its cause and focus on the process improvement [4]. Apply the work study method and technology into the on-site management of the production of the enterprises, and attach great importance to the improvement on the work space [5]. Apply the work study method to optimize and design the production process of the core product production line of GY. Take the combination switch assembly line of some auto parts enterprise as the research object, and carry out balance improvement design on the production line through the two-hand work analysis, fixture design, workbench layout design, station re-division, etc. All these literatures are involved in applying the industrial engineering method into the corporation improvement [6]. However, the entry point is relatively single. Based on the predecessors' research, this paper shows the importance and necessity of the industrial engineering, and applies the process improvement method to analyze and improve the problems in the enterprises from multiple angles.

This paper takes the assembly production line of the laptop battery module of Company A as the research object. Aiming at the operation, carrying, inspection, waiting and storage in the process, this paper makes detailed analysis. From the process, operation, action and layout, it identifies the problems in the process through "5W1H" and "ECRS", makes improvement, and finally solves the bottle-neck and improves the balance rate of the production line.

II. CURRENT STATUS AND PROBLEM ANALYSIS OF PRODUCT PRODUCTION PROCESS

A. Current Status of Product Production Process

Company A is specialized in developing and assembling the battery modules. It is committed to the sustainable development, new and advanced technology, and excellent quality. The products are popular in domestic and foreign markets. At present, an assembly workshop of the battery module has 5 same production lines. During the operation, many problems are exposed, which leads to low production capacity. It cannot meet the sustainable development demands of the company and needs urgent development. A production line is regarded as the research object. Other improvement methods are similar.

This production line is mainly in charge of the assembly and of the laptop batteries. There are 16 stations. The packaging company applies the stopwatch chronometry method for each station operation time, carries out tests for many times and obtains the mean value. It can obtain the operation time figure required by each station as shown in Figure 1.

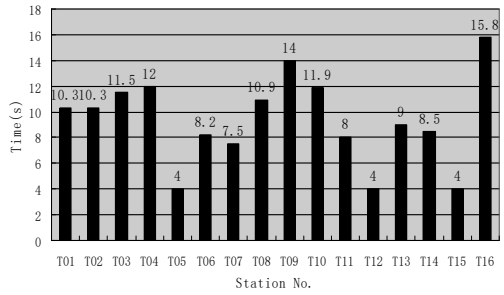

Figure 1. Bar graph of each station operation time (pre-improvement)

B. Problem Analysis

Apply the related technology in the work study, carry out the detailed investigation research on the production site and process, and find out the problems are related to the following aspects:

(1) Weak balance of the production line

The takt time (T.T) of the whole production line is: T.T= (daily effective working time) / (customer's daily demands)=27600s/2500pcs =11.04s/pc.

(Note: The production line performs 9h working system, the morning meeting and cleaning time takes 10 min respectively, and the lunch time takes 1 hour, the daily working time is 7 hours and 40 minutes, i.e. 27,600s, and the daily order quantity is 2,500pcs.)

From Figure 1, the balance rate of the production line can be calculated. The computation formula is: Balance rate=total operation time/(the longest operation time) * number of the stations=149.9/（15.8×16）×100%=59.3%. Thus, it can be seen that 40.7% of the time is wasted due to the imbalance of the production line. Besides, from Fig.2, Station T09 and T16 are the bottle-neck stations. They require 14s and 15.8s respectively. It further exceeds the T.T. Only if the operation time of each station is close to the T.T, a flow production line can be realized. Therefore, Station T09 and T16 are regarded as the key points of improvement.

(2) The task distribution of each station is not even

From Figure 2, the busy time for each station is not even. Some stations have surplus production capability. The shortest operation time is only 4s (Station T05, T12 and T15), while the longest time is 15.8s (Station T16). The difference between the shortest and longest operation is about 4 times. Namely, the time for Station T16 to finish a task is equal to that Station T05/T12/T15 to finish around 4 tasks, which absolutely leads to stacking up of the work-in-process products among the station, long waiting time of the equipment and personnel, low utilization rate of the labor time, and unfair operation of the operators, etc.

(3) Too much stacking of work-in-process production

From the production site, there are at least 5 pieces in the work-in-process product warehouse of each station. Too much work-in-process products will hide the waiting wastage, and also force the operation space to become larger, and distance become larger among the equipment. Then, it gives rise to other wastage, such as carrying, moving, etc. Moreover, it is quite easy to cause rejects, which directly results in the increasing of the manufacturing cost.

(4) Unreasonable plane layout

The distance between each station of this assembly production line is inconsistent. The shortest and longest distance is 0.8m and 1.4m respectively. For instance, the distance between packing parts into case and test is 1.4m, which is much long. Although it is automatic transmission in the production line and manual carrying is unnecessary, the long carrying distance is a great waste of time.

III. IMPROVEMENT PROPOSAL DESIGN

This paper mainly applies the procedure analysis, operation analysis, action analysis, layout and routing analysis from the work study, and carries out detailed investigation on the product assembly procedure. The specific process is as follows: firstly apply "5W1H" questioning technique to raise questions about each activity from the purpose, cause, time, location, personnel and methods, identify the problems, and then apply "ECRS" (Eliminate, Combine, Rearrange, Simple) principles, improve the bottleneck of the assembly line according to the action economy principle and assembly line balance theory, reduce the wait and improve the productivity.

A. Process improvement

(1) Process merging

1) Merge the process of T05 and T06. Apply 5W1H questioning technique, propose questions about each process one by one, identify and solve the problems. Take T05 inspection process as an example and make analysis.

Question: what is the inspection content?

Answer: Check whether the battery soldered by the previous process spot welder is popped, soldered in incorrect position, or the soldering is missing, etc.

Question: Can the inspection process be canceled?

Answer: No. If some rejects occur due to the battery soldering problems and they are put into the following processing process, the following processing step will be meaningless.

Question: Who takes charge of the inspection?

Answer: A quality people do the inspection.

Question: The inspection time is so short. Can it be merged with other processes?

Answer: Yes. ……

After repeated questioning and identification, the inspection process is really necessary. However, it can be merged with T06 station. As the main inspection content is to check if there is popped status, deviated soldering or missing soldering after the battery soldering, the content is relatively simple, and special equipment is not required, as it is finished by visual inspection, so that the ordinary operator is qualified to do it; merge T05 and T06, and the inspection process is completed by the operator who applies the two-side adhesive. After merging, the process of putting down and catching can be removed. The total operation time is 11.2s, and a quality people can be reduced.

2) Cancel the one-hand operation of T13 (Put into the case), and merge T12 and T13. Cancel the waste of the one-

hand operation: Case packing process of T13 is undertaken by an operator to put the battery with the internal barcode and PCBA into the slot of the under cover of Case, and cove the case. The operation time is 9s. At present, the battery and PCBA are placed on the left hand of the operator. The left hand is to pick the battery and PCBA separately, so there is a waste of one-hand operation. The improvement proposal is: place the PCBA on the worker's right hand, and after the operator puts on the internal barcode, he can pick the battery with the left hand, and pick the PCBA with the right hand, and then put them into Case together. In this way, the operation time can be reduced by 1s.

Merging process: Putting the barcode in T12 station is undertaken by the operator who puts the barcode on the battery, with the operation time of 4s. As the operation time is much less than the taken time, workers always wait there. However, after T13 is improved, the operation can be reduced to 9s, which is less than the taken time. After T12 is merged with T13, the operation can be 12s and an operator can be reduced.

(2) Operation improvement

At T09, it takes long time (28s) to finish a single piece. As two operators in this station operate 2pcs parts at the same time, the taken time of this station is 14s, which is bottle-neck station. At present, in this station, two operators complete the AT wire soldering and hot melting glue application independently. The improvement method is: carry out labor division for two operators, one operator specifically solders AT wire and another one applies the hot melting glue. Therefore, it can reduce the time of picking the tools. The total time can be reduced by 4s, i.e. the taken time of this station is reduced to 12s.

(3) Re-arrangement of the process

From Figure 1, the labor time required by T15 station requires is 4s, while that required by T16 station is 15.8s, which presents the labor time difference from two adjacent stations is relatively big. The excess production capacity happens in T15 station, while serious accumulation of the work-in-process products happens in T16 station. Under the circumstance that has no impact on the product quality and other operations, it is necessary to consider re-arranging the process of both stations. T16 station includes barcode scanning, packaging and casing containerization which are separated from each and split table. The equipment for scanning the barcode is easy to be moved. Therefore, it is feasible to move the barcode scanning to T15 station. After adjustment and stopwatch measurement, the labor time for T15 and T16 is 8.5s and 11.3s respectively, which is close to the taken time.

B. Improvement of Plane Layout of the Production Line

The distance between each station of the production line is inconsistent. The distance between some stations is relatively long, which leads to long moving distance and thus a great waste of time. As this production line is linear layout. After careful measurement and test, the best suitable distance between the stations is 0.8m, as the width of each fixture plate on the production line is 35cm. To keep the production buffer of two products between the stations not only can ensure the smooth status of the production process, but also can shorten the moving time of the semi-finished products on the production line.

C. Process Flow Chart after Improvement

After the improvement above, the process flow chart can be obtained as shown in Table 1. The balance rate of the production line is 145.9/(12×14)=86.8%.

TABLE I PRODUCT ASSEMBLY FLOW PROCESS CHART (POST-IMPROVEMENT)

Station No.	Operation Description	Dist-ance/m	Time/s	Number of people	**Proce-ssing**	**Carry-ing**	**Insp-ection**	**Wait-ing**	**Sto-rage**
					○	⇨	□	D	▽
T01 T02	Put on nickel plate of upper mound		10.3	1	●	⇨	□	D	▽
	Pass onto the next station	0.8	4		○	➡	□	D	▽
	Put on nickel plate of lower mound		10.3	1	●	⇨	□	D	▽
	Pass onto the next station	0.8	4		○	➡	□	D	▽
T03	Put on the battery and inserted die mound		11.5	1	●	⇨	□	D	▽
	Pass onto the next station	0.8	4		○	➡	□	D	▽
T04	Use spot welder to weld the batteries		12	1	●	⇨	□	D	▽
	Pass onto the next station	0.8	4		○	➡	□	D	▽

T05	Inspection, apply two-side adhesive tape, performing		11.2	1	●	⇨	■	D	▽
	Pass onto the next station	0.8	4		○	➡	□	D	▽
T06	Apply insulation sheet		7.5	1	●	⇨	□	D	▽
	Pass onto the next station	0.8	4		○	➡	□	D	▽
T07	Molding, apply scotch tape		10.9	1	●	⇨	□	D	▽
	Pass onto the next station	0.8	4		○	➡	□	D	▽
T08	Solder AT cable and apply the hot melt adhesive		12	2	●	⇨	□	D	▽
	Pass onto the next station	0.8	4		○	➡	□	D	▽
T09	Solder the batteries		11.9	2	●	⇨	□	D	▽
	Pass onto the next station	0.8	4		○	➡	□	D	▽
T10	Gluing		8	1	●	⇨	□	D	▽
	Pass onto the next station	0.8	4		○	➡	□	D	▽
T11	Put on the internal barcode, Put into the case		12	1	●	⇨	□	D	▽
	Pass onto the next station	0.8	4		○	➡	□	D	▽
T12	Test		8.5	1	●	⇨	□	D	▽
	Pass onto the next station	0.8	4		○	➡	□	D	▽
T13	Put on external barcode, scan the barcode		8.5	1	●	⇨	□	D	▽
	Pass onto the next station	0.8	4		○	➡	□	D	▽
T14	Packaging, casing containerization		11.3	1	●	⇨	□	D	▽

IV. IMPROVEMENT EFFECT EVALUATION

The pre- and post-improvement data comparison is shown in Table 1. The effect after the improvement is as follows:

(1) The process procedure of the battery assembly production line after improvement is more scientific and reasonable. Through the improvement, the number of stations for the whole production process can be reduced from 16 to 14. There are 2 processes merged (T05 and T06, T12 and T13), 1 item rearranged (T15 and T16), and 2 workers reduced, which enhances the continuity and rhythmicity of the production process, reduces the workers' waiting time, realizes the reasonable allocation of the production elements, reduces the accumulation of the work-in-process products, as well as the labor cost.

(2) Shorten the transportation distance of the products. Through the improvement of the station layout and merging of the stations, the carrying distance is reduced from 14.6m to 10.4m. The production line length is reduced and the structure becomes compact, which saves much space and shortens the transportation time and distance.

(3) Simplify the operation and reduce the labor intensity of the workers. After improvement, to solder AT wire and

apply the hot melting glue becomes simpler. The process of putting the parts into the case relieves the workers' fatigue after one-hand operation, reduces their labor intensity and improves the production efficiency.

(4) Improve the balance rate of the production line. After improvement, the balance rate can be greatly improved from 59.3% (before the improvement) to 86.8%. Besides, the waste resulting from the imbalanced stations can be reduced.

TABLE 1. PRE-IMPROVEMENT AND POST-IMPROVEMENT EFFECT COMPARISON

Item Category	Pre-improvement	Post-improvement	Improvement effect
Operation Time/s	149.9	145.9	Reduce the 4s
Carrying Distance/m	14.6	10.4	Reduce the 4.2m
Carrying Time/s	73	52	Reduce the 21s
Number of Stations/pc	16	14	Reduce 2pc
Required Number of People	18	16	Reduce 2 people
Balance Rate	59.3%	86.8%	Increased by 27.5%

V. CONCLUSION

This paper applies the work study theories and methods into the practice of Company A. Under the condition without the increasing of the investment, through the re-layout of the production line, adjustment and optimization of the processes, it solves the bottle-neck stations, improves the efficiency of the production line, shortens the carrying distance, and achieves better economic effect. This method can be used by the similar enterprises for reference.

REFERENCES

[1] W. L. Gui. "The Analysis of Applying Work Study Methods to a Certain Company", Industrial Engineering and Management, vol. 11, No. 04, pp. 123-126, 2006.

[2] S. H. Lan, D. T. Li. "Application of Work Study to the Redesign of a Stator Assembly Line", Industrial Engineering Journal, vol. 13, No. 03, pp. 126−129, 2010.

[3] X. H. Liu, H. P. Xu, H. Hong. "The Application of Work Study in the Production Site Management of One Enterprise",Modern Manufacturing Engineering vol. 2, No. 06, pp. 57-60, 2012.

[4] X. L. Zhang, Y. F. Wang, T. Y. Xie, et al. "Enterprise Production Line Optimization and Re-design Based on Work Study Methods—a Case Study", Modern Manufacturing Engineering, vol. 3, No. 03, pp. 27-32, 2015.

[5] R. Y. Shao, J. Lu, H. Y. Xu, et al. "Application of Work Study in the Improvement of Combination Switch Assemble Line", Group Technology & Production Modernization, vol. 2, No. 04, pp. 36-42, 2014.

[6] F. Guo, S. Li. "Research on Problems in Application of Work Measurement Technology", Industrial Engineering Journal, vol. 6, No. 05, pp. 54-65, 2003.