The measures to improve the manufacturing process by using the lean concept for hard disk drive industry

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Abstract

In this paper, the lean manufacturing method using value stream mapping was adopted to investigate and analyst the value of activities throughout production processes in order to eliminate the production wastes. While the simulation technique was used to support decision for proposing measures to increase a firm productivity in the case study, a hard disk drive component manufacturer. The results shown that the purposed method could reduce production cycle time (takt time) from 21.18 to 19.89 s., workforces from 10 to 8, work-in-process about 60% and eliminate production bottleneck. That led to more efficiency (12.19% increase) in production line balancing, indicating more effective production lines. Furthermore, improvement of production process continued progressively in the step of adhesive dispensing and the one of drying the glue by UV light. It led to ability to control the amount of glue dispensing more effectively, increasing quantity of work (33%) (from one syringe of glue) from 3,078 into 4,104 pieces of work per syringe, and reducing cost of glue (25%).

Keywords*: Lean Manufacturing, Value Stream Mapping, Simulation techniques, productivity improvement*

1 Introduction

The huge demand of electronic products has driven rapid growth in the hard disk drive and its components industries. Therefore, manufacturers should increase their capability and management flexibility for a rapidly change in the real world in order to reduce operating cost to meet customer demand without any delay and to emphasize on value creation maximization for customer satisfaction.

This study presents guidelines for value analysis of activities in each work step throughout all production lines, using value stream mapping as a tool according to the concept of lean manufacturing system [1], [2], [3] to increase a case study company's capability by adding the value to operation and eliminating wastes in production process. This could reduce cost of production along with focusing on quality of products. Moreover, the simulation technique using ARENA software was applied as the VSM complementary tool to creating the simulation model to support the decision for proposing measures that caused the advantage during implementing the plan and assessment stages such as imitate patterns of work on assembly lines that use an automatic machine for production [4], [5]. This can be used to deal with uncertainty and create different scenarios of works in process, production cycle time (takt time), production bottleneck and machine utilization.

2 Literature Reviews

Mathew et al. [6] suggested that application of lean principles begin from grouping for continuous improvement and training on the topics of Visual Factory Management, Statistic Process Control (SPC), and Standard Operating Procedure (SOP). The study of Linker et al [7] identified factor for consideration of applying lean manufacturing principles. That factor is reduction setup time for machines, using quick production change technology; and design of tools and equipment for error prevention in manufacturing. Later the study of Spann et al. [8] demonstrated that mostly lean manufacturing systems emphasized quality, cycle times, and customer responsiveness; consequently, work balancing or production line balancing were applied to a lean manufacturing system.

In recent years,value stream mapping (VSM) has emerged as the preferred way to implement lean. Value stream mapping is used to described supply chain networks. Fawaz et al [9] applied lean principles to doing research in a company. The technique used in the research was value stream mapping, showing a current state (VSM:Current state) of the company by specifying sources of waste. The concept of lean manufacturing was applied to modification for value added in process until it was developed into future state map (VSM:Future state). The use of simulation technologies is very popular in modeling complex manufacturing systems, because a simulation model can give early insights and estimates of behaviours for very complex systems. Yang et al. [10] tried applying some principles of lean manufacturing system by creating a two-plan simulation model considered as employing the aspect of push and pull systems. Efficiency of operation was evaluated by the simulation through Arena program. According to operating results, it found capability to modify the manufacturing system, for example, 78% reduction of production lead time, an increase of proportional value from 5.9 to 25.9, reduction of work quantity during production process, and elimination of bottlenecks of an assembly line.

For industries of electronic component manufacturing such as a complicated but flexible manufacturing, Soontorn et al. [11] studied guidelines of production efficiency improvement by creating a simulation model in consistency with current manufacturing processes of assembling read head actuator of ROM (Read Only Memory) and modifying simulation models for many options in order to compare differences in results of the shortest standard production time. The study results demonstrated the optimal option which could cause a 22% reduction in the standard time of production from 53.8 to 41.7 minutes.

3 Step of procedure

3.1 *Value Stream Mapping for analysis and improvement*

The case study is a hard disk drive component manufacturer which produces Hook Up component. The firm works 21 hours a day and 6 days a week. The focus of VSM is on product group with the highest demand quantity of aggregate production based on the past 6 months data (July – December, 2009) which was approximately 44.5% of total quantity of aggregate production. Product groups, of this study, were categorized into 2 main production lines. The first line is the assembly line of components called FCOF (Flip Chip On Flex) - placement of circuit components on the part called Flex. The second line was the assembly line of Hook Up functioning as assembling Flex to the actuator arm to achieve the final product called APFA (Arm Pivot Flex Assembly). The current state map is constructed as shown in Figure 1 by collecting data of all activities that are required throughout the 2 main process lines, beginning with the raw material procurement and ending with the shipping to customer.

The lead time of raw material ordered from a supplier was 2 weeks, while the product delivery to customers was 7 days. Also, production cycle time was totally 1168 seconds. From VSM, a bottleneck was observed in the production line at SMT placement step, with the highest production cycle time 20.99 seconds. Therefore, the simulation model using ARENA was created to solve problems during production process.

3.2 *Data analisis used for simulation*

Data used for the simulation model included the entering rate of work pieces and working time in each step. Data distribution patterns were analysed by the Input Analyzer, a basic tool of ARENA in order to test input data distribution to find distribution patterns. Figure 2 shows an example of using Input Analyzer to find data distribution patterns with hypothesis testing on probability distribution (Goodness of Fit Test) through the Kolmogorov-Smirnov test, since the number of data is less than 50 data. The p-value was taken into account for choosing data distribution patterns. The level of statistical significance used in this research was 0.05. If the p-value is above 0.05, a distribution pattern presented by the program will be accepted.

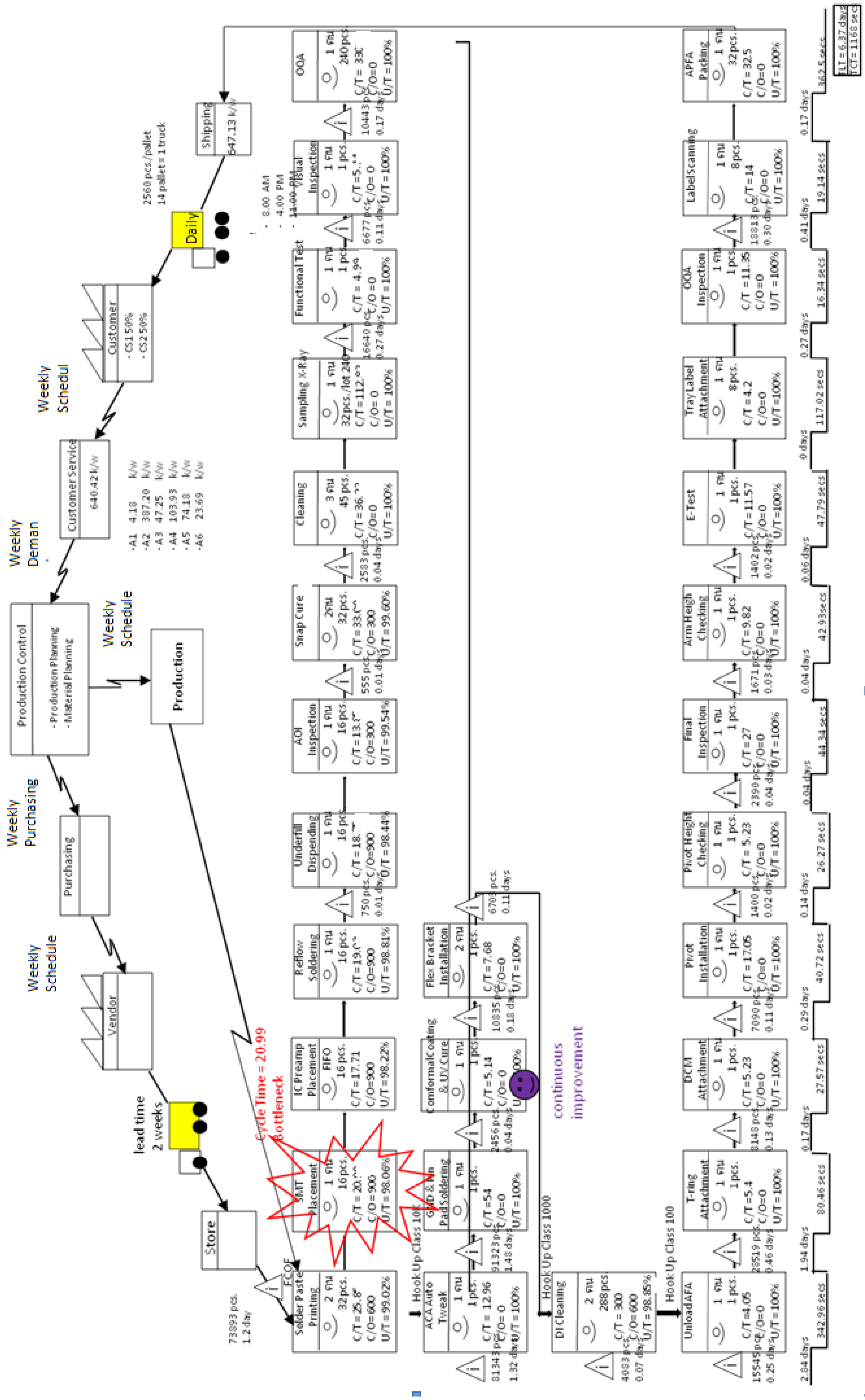

Figure 1: Current state map.

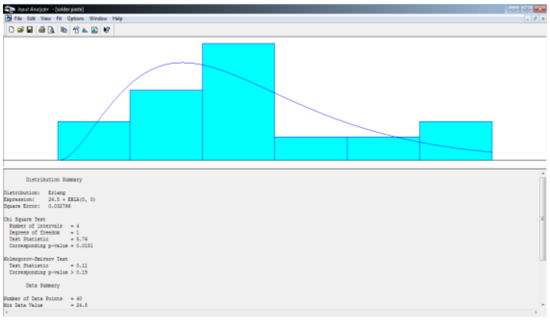

Figure 2: An example of using Input Analyzer to find data distribution patterns

3.3 *Creating the Simulation Model of the Production Process*

The simulation model was applied to hard disk drive components in this study in order to imitate work patterns in the part of the assembly line of FCOF. There were 7 operating steps mostly requiring the automatic machine. The obtained pattern could help manufacturer in testing and studying the effects occurred in any changes or modification of the system. It led to system development and analysis for increased efficiency. To create the simulation model, there were 3 parts which were considered in the analysis of work patterns in FCOF assembly line.

Entity Arrivals: The entities in this research were Flex components which were put into the pallet. One pallet consisted of 16 Flex components. For this simulation model, it determined entity arrivals characterized by the pallet.

Resources: Resources used in this study were defined as machines used in each process and in each step of assembling FCOF. An automatic machine was used in most steps of assembling.

Queue during procedure: Characteristics of queue during operating steps of FCOF assembly could be under the First In, First Out (FIFO) rule; in other words, an object entering the process first could circulate before other objects. The next object could enter the process when the previous object finished the process.

3.4 *Validity Testing of the Model*

Validity of the created model was considered by data on average actual working time of the process compared with working time obtained from the simulation model. The number of replication was 30.

From the Table 1, it demonstrated that actual working time was fall in between the period of time obtained from the simulation model.

Table 1: Comparison between actual production time and time obtained from simulation

Production Process	Avg. Actual Working Time	Avg. Working Time From Simulation	
Solder Paste Printing	25.85	25.77-25.87	25.82
SMT Placement	20.99	20.98-21.03	21.00
IC Preamp Placement	17.71	17.60-17.72	17.67
Reflow Soldering	16.03	15.43-15.57	15.48
Under Fill Dispensing	18.75	16.69-19.81	19.74
SMT,AOI inspection	13.85	13.83-13.89	13.85
Snap Cure	33.09	33.03-33.13	33.09

Hypothesis of population mean was based on data on actual working time of the process in the existing system to be compared with averages from the simulation model.

Statistical hypothesis: $H_0 : \mu_0 = 146.28$

$H_1 : \mu_0 \neq 146.28$

Test statistics :

$$Z = \frac{\overline{X} - \mu}{S/\sqrt{n}} \quad \text{; in case } n \geq 30 \qquad (1)$$

$\overline{X}$ = Average working time of the process from simulation

μ_0 = Average working time of the process in the real system

S = Standard deviation of working time of the process from simulation

n = Number of times for running the program (there in n=30)

$\overline{X} = 146.62$ S = 0.974

$\mu_0 = 146.28$ n = 30

From the equation (1)

$$Z = \frac{146.62 - 146.28}{0.974/\sqrt{30}}$$

$$Z = 1.911$$

From statistical testing, it found that the test statistic value was 1.911 within the range of +1.96 and -1.96. Thus, primary hypothesis or null hypothesis (H_0) at a significance level of 0.05 could be accepted, or it could be said that there was no significantly difference between the average of actual working time and the working time from simulation.

In addition, quantity of daily production of the simulation model was not different from the product quantity with the existing production. Therefore, it could be concluded that the created simulation model was valid and could be applied in real situations.

3.5 *Calculation of Numbers of Rounds in Simulation*

To examine accuracy of procedure, the program was determined to repeat 29 runs according to equation (2). To do that, 30 preliminary runs were performed then the averages from each repetition were used for calculating the highest standard deviation to be used as a reference for finding appropriate numbers of cycle in repeat processing. The formula for calculating numbers of cycle in repeat processing for this experiment was as follows.

$$n = \left[\frac{z_{\alpha/2} * s}{e}\right]^2 \qquad (2)$$

The result from the simulation system could be used for calculation to find error from the equation of Harrell et al [12].

$$e = \frac{(t_{\alpha,n-1})s}{\sqrt{n}} \qquad (3)$$

$$e = \frac{2.0452 \times 0.974}{\sqrt{30}}$$

$$e = 0.36$$

substituted in the equation (2)

$$n = \left[\frac{1.96 \times 0.974}{0.36}\right]^2$$

n = 12.28 or 29 rounds

where n = numbers of cycle in simulation
s = standard deviation
e = error

Calculation of suitable numbers of cycle determined a 95% confidence level, $Z_{0.025}$=1.96, and the standard deviation (s= 0.974) in the process. The error value allowed in simulation was 0.36 second. When substituted in the equation (2), it got n=28.12 rounds, which could round up to 29 rounds.

4 Data analysis from the simulation mode

The aforementioned steps of creating the simulation model could be used for creating the one of the assembly line of FCOF, which could be completed by Arena program as Figure 3.

There operating steps mostly required the automatic machine. ARENA software is a dynamic or an operating model of a system or problem entity that mimics the operating behaviour of the system or problem entity. For fast construction of complex manufacturing systems.

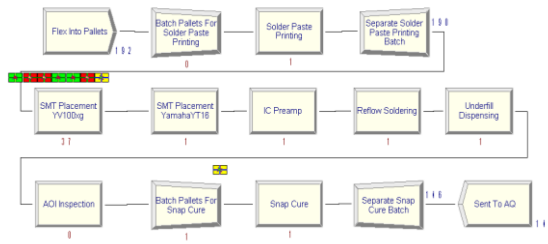

Figure 3: Simulation model of the assembly line of FCOF, created by Arena

The obtained simulation model will be used to evaluate the performance of system and compare the results with an existing traditional manufacturing system. From varying efficiency of machines through the simulation model.The model will also be used by the management team for continuous improvement process to increase throughput, identify bottleneck and work-in-process, and identify machine and labor utilization.In this research, there was operation on improvement of operating steps and the step of SMT placement which were considered as production bottleneck.

5 State of blackground problem

In the case study, the factory employed 5 versions of machines in the production processes, which are 1) YamahaGY200L, 2) YamahaYS24, 3) YamahaYV100xg, 4) GSMxs, and 5) YamahaYT16. As for the versions YamahaYV100xg, GSMxs, and YamahaYT16, there should be cooperattion so that manufacturing steps could be completed. Thus, four simulation models are presented as follows.

Model 1: a current simulation model, using the machine version YamahaGY200L in the step of SMT placement and requiring 10 employees.

Model 2: a simulation model, using the machine version Yamaha100xg to work together with the machine version

GSMxs in the step of SMT placement and depending on 9 employees

Model 3: a simulation model, using the machine version Yamaha 100xg to work together with the machine version YamahaYT16 in the step of SMT placement and requiring 9 employees.

Table 2: The result from the simulation model

Model			Work Pieces (pcs./hr)	Number of Operator (man)	Max WIP (pcs.)	Takt Time (sec/pallet)	Labor Productivity (pcs./hr/man)	Average Utilization (%)	Line Balance (%)
Before Improvement	1	YamahaGY200L	2720	10	160	21.18	272	80.48	56.72
After Improvement	2	YamahaYV100xg GSMxs	2144	9	64	26.87	238	79.23	72.82
	3	YamahaYV100xg YamahaYT16	2336	9	48	24.65	260	86.93	73.62
	4	YamahaYS24	2896	8	64	19.89	362	83.68	68.91

Model 4: a simulation model based on machine version YamahaYS24 version in the step of SMT placement, requiring 8 employees.

The duration used in simulation was the time required to operate one job, which was 7 working hours. It was assumed that there were no defect in work pieces in the system. Also, there was no system failure. The result from the simulation model is presented as in Table 2.

The simulation results were illustrated in many scenarios under different production rate, product quantity, labour productivity per employee, and efficiency of production line balancing.

When considered by quantity of demand, product groups, in the study, increased from 53370 to 58707 work pieces a day, or it could be said that the takt time of the company reduced from 22.66 to 20.60 seconds. However, for manufacturing capability before improvement, the takt time of production process was 21.18 seconds higher than that of customer's takt time, thus not meeting customer demand.

Therefore, the most appropriate model for current situations of the company was the fourth one, using the machine version YamahaYS24 in the step of SMT placement and requiring 8 employees. This model can meet customer demand. The takt time of production process is 19.89 less than that of customer responsiveness, causing a 60% decrease in quantity of works during the process. That could eliminate production bottlenecks, causing a 12.12% increase in balance of production lines and reducing numbers of employees from 10 to 8 people by allowing an employee to be able to do many duties. For improvement as indicated, in the first step, it attempted to reduce numbers of employees from three to two people for preparing pieces of work. Also, the rest of employees had good knowledge of using more than one machine.

As for the second and the third models, they yielded more efficiency of production line balancing 16.1% and 16.9%, respectively. That suggested optimization of resource utilization and reduced waste occurring during the production process. That was suitable for modification to prepare for changes if quantity of product demand changed.

6 Continuous improvement of production process

The improvement of production process in the step of glue dispensing and glue drying by UV light caused possibility to control quantity of adhesive dispensing more effectively. The weight of glue on a piece of work should be about 2.5±0.7 mg. Also, there must be adhesion between joints of the wire line and VCM solder both at the start wire and at the end wire. Factors affecting glue value on a piece of work were presented with the fishbone diagram as Figure 4.

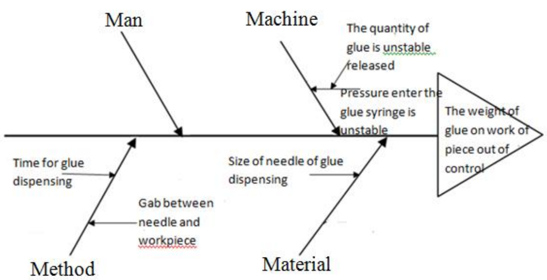

Figure 4: Analysis of factors affecting glue value on a piece of work by the fishbone diagram

Solution

Speed control was added to pressure pump which transferred it to two syringes of glue of Rotary UV Machine to be used in pressure adjustment. Air then entered the glue syringes as Figure 5.

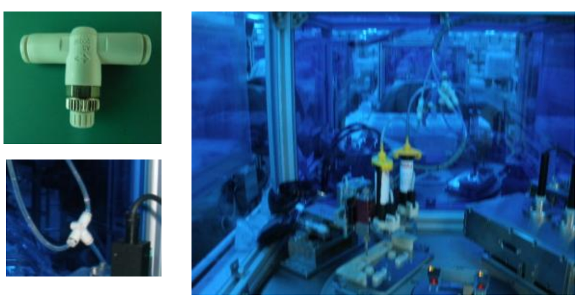

Figure 5: Rotary UV Machine functioning as an installer of speed control

Although adding speed control helped in control of glue dispensing, the level of pressure adjustment for entering glue syringe could still not be clearly defined. At present, pressure adjustment at speed control can be done by an employee who operates in that machine. Also, it bases on experiences and frequent pressure adjustment which can waste time and cause incomplete efficiency. Thus, procedure was improved by increasing pressure gate as Figure 6 to be as an indicator of pressure released to glue syringes. In addition, it included distribution syringe of pressure pump so that air pressure could be controlled easier.

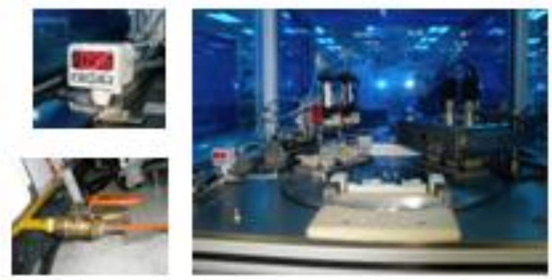

Figure 6: Rotary UV Machine functioning as an installer of speed control and pressure gate.

7 Data collection

Collection of operating data was conducted by data recording on pressure into two syringe of glue and weight of glue on work pieces without controlling their values and adjusting pressure. The collected data on pressure to the glue weight were analyzed to study its effects and present suitable ranges of wind pressure for glue dispensing to meet the production standard at 2.5±0.7 milligrams.

The data collection showed that samples of pressure were various. Thus, for appropriate analysis of variance and consistency with current working conditions of the company in a case study, ranges of pressure into the syringe for analysis of variance were categorized into 5 suitable ranges: 0.40-0.55 , 0.56-0.70, 0.71-0.85, 0.86-1.00, 1.01-1.15 MPa. The pressure ranges for analysis are shown in Table 3.

Table 3: Pressure ranges for analysis of varience to find suitable ranges for glue dispensing

Pressure Ranges (MPa)	Size of data
0.40-0.55	54
0.56-0.70	78
0.71-0.85	24
0.86-1.00	42
1.01-1.15	42

8 Data analysis

One-way ANOVA was applied to data analysis. Analysis of variance about glue weight on work pieces was processed by considering both needle in and needle out - type glue dispensing syringe through SPSS for windows V11 at a significance level of 0.05.

Hypothesis

$$H_0 : \mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5$$

H_1 : There is at least one different pair of μ

8.1 *Data Analysis of Weight of Glue on Pieces of work from Internal Needle-Type Glue Dispensing Syringe.*

The results of data analysis of variance on glue weight on pieces of work from internal needle-type glue dispensing syringe were shown as the table 4.

Table 4: Results of data analysis of variance on glue weight on pieces of work from internal needle glue dispensing syringe

ANOVA

Weight of Glue

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	26.553	4	6.638	325.371	.000
Within Groups	1.938	95	.020		
Total	28.491	99			

According to results of data analysis as mentioned above, it showed that the calculated value of statistical significance was lower than the statistical significance level of 0.05. Therefore, the null hypothesis was not accepted, and it could be concluded that from five pressure ranges, weights of glue on pieces of work from internal needle-type glue dispensing syringe were significantly different.

Table 5: Result of multiple comparison test about glue weight on pieces of work from internal needle-type glue dispensing syringe for each pressure range

Duncan[a]

Range of Pressure	N	Subset for alpha = .05 1	2	3	4	5
1	20	1.9030				
2	20		2.5045			
3	20			2.7625		
4	20				3.0955	
5	20					3.4070
Sig.		1.000	1.000	1.000	1.000	1.000

Based on multiple comparison test as shown in the Table 5, it could be concluded that glue weights from internal needle-type glue dispensing syringe for each pressure range were significantly different for all pairs. T-test was used for considering appropriate pressure ranges in glue dispensing. Averages and standard deviation values of glue weights on pieces of work were applied to testing with glue weight to meet the production standard at 2.5 milligrams. The results were shown in the Table 6.

Table 6: Results of T-test of each pressure ranges in comparison with the manufacturing standard

One-Sample Test

	Test Value = 2.5 t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference Lower	Upper
0.40-0.55	-16.238	19	.000	-.5970	-.6739	-.5201
0.56-0.70	.148	19	.884	.0045	-.0593	.0683
0.71-0.85	6.687	19	.000	.2625	.1803	.3447
0.86-1.00	18.403	19	.000	.5955	.5278	.6632
1.01-1.15	59.460	19	.000	.9070	.8751	.9389

The results of finding suitable pressure values showed that the obtained glue weight from glue dispensing within the pressure range from 0.56-0.70 MPa was not significantly different from the one with the manufacturing standard at 2.5 milligrams.

G.Data Analysiss of Weight of Glue on Pieces of Work from External Needle-Type Glue Dispensing Syringe.

It was conducted in the same way as the data analysis on glue weight on pieces of work from internal needle-type glue dispensing tube.

The obtained results helped in finding the suitable pressure in glue dispensing from external needle-type syringe to meet the manufacturing standard at 2.5 milligrams significantly, that is, the wind pressure range of 0.56-0.70 MPa.

9 Control limit calculation and chart building

Control Limits for the X-bar Chart

$$\text{Upper Control Limit (UCL)} = \bar{\bar{X}} + A_2 \bar{R} \quad (4)$$

$$\text{Central Line} = \bar{\bar{X}}$$

$$\text{Lower Control Limit (LCL)} = \bar{\bar{X}} + A_2 \bar{R} \quad (5)$$

Control Limits for the R Chart

$$\text{Upper Control Limit (UCL)} = D_4 \bar{R} \quad (6)$$

$$\text{Central Line} = \bar{R}$$

$$\text{Lower Control Limit (LCL)} = D_3 \bar{R} \quad (7)$$

(A_2, D_4, D_3 = Factor for Control Limits)

9.1 *Control chart on glue weights on pieces of work*

From an analysis to find suitable wind pressure ranges in glue dispensing, it showed the suitable range in glue dispensing from internal needle-type syringe to meet the standard, that is, the pressure range of 0.56-0.70 MPa. In addition, the result of calculation by the equation(4),(5),(6),(7)are presented in the control chart as shown in the Figure 7.

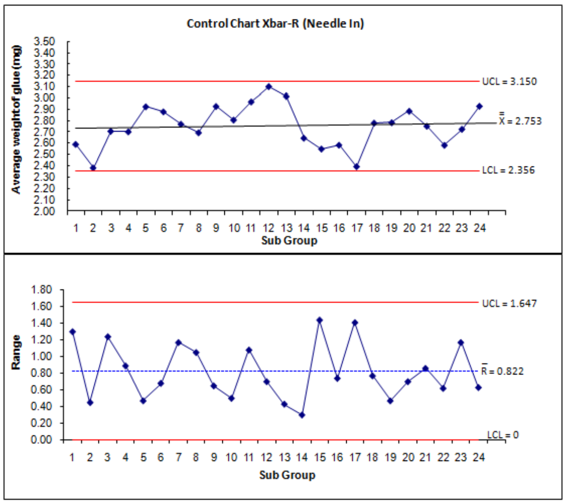

Figure 7: Control chart on glue weights on pieces of work from internal needle-type glue dispensing tube

The first improvement by adding speed control and using a pressure gauge to control pressure and glue dispensing led to convenience in pressure control and knowing the suitable wind pressure range that would make the glue weight on pieces of work to meet the indicated standard. From the experimental results, the suitable pressure range was 0.56-0.70 MPa. The result from the created control chart was helpful for considering the glue weight on pieces of work with the pressure control under control and for knowing the quality of products before delivery to customers. The result from process improvement was shown as in Table 7. There was a 33% increase in work quantity from one glue syringe. This reduced waste from overusing glue unnecessarily and led to a 25% cost reduction because of better glue quantity control and more standardized operating steps. In addition, it indicated time of adjustment and setting wind pressure from a glue dispenser, resulting in an increase in the average of pieces of work from both internal and external needle-type tubes from 402 into 450 pieces per one hour.

Table 7: Results from improvement of the step of dropping glue and drying glue with UV light

Build plan Refer MPS	Procedure	quantity from one glue syringe	Cost (Bath/Syringe)	Total Cost
1,700,000	Before Improvement	3,078	744	410688
	After Improvement	4,104	744	308016

10 Conclusion of indicators for production process improvement by the concept of Lean

Reduction of production cycle times

The most suitable option from models to current situations of the company in the case study helped eliminating production bottlenecks, causing a 12.19% increase in production line balancing and reduction of cycle times, which could increase productivity from 2,720 to 2,896 pieces per one hour.

Mode of assignment

From the traditional production, one employee could do only one duty. After improvement into lean manufacturing, one employee could do more than one piece of work. For example, an employee who prepared pieces of work before putting them into a machine for the first step could also control the machine for the next step. That improvement could reduce the number of employees from 10 to 8 and increase labor productivity per one worker from 272 to 362 pieces per one hour for the assembly line of components, FCOF.

Reduction of waste from inappropriate processes

From the step of dropping glue and drying glue with UV light, it found waste from inappropriate processes and frequent machine adjustment led to inefficient operation. However, continuous operation of production improvement resulted in a 12% increase in the average of works from both two kinds of glue tubes. That reduced overuse of glue unnecessarily, caused more pieces of work from one glue tube (1,026 pieces), and led to a 25% reduction of glue costs.

Acknowledgments

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