# Efficiency Improvement Using Simulation Technique in Hard Disk Drive Arm Cleaning Process

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# Efficiency Improvement Using Simulation Technique in Hard Disk Drive Arm Cleaning Process

Chaithep HEMRATTANAKORN* and Suntichai SHEVASUTHISILP*

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The final process of hard disk drive arm manufacturing is the hard disk drive arm cleaning process. Currently, the product demand is rapidly growing and exceeding the process capacity. Hence, the aim of this paper is to reduce a cycle time of the process to support the higher demand in the future while the product quality is not affected. The study is focusing on the simulation model of the cleaning machine. The simulation model was developed to determine the line balancing of this process with $2^k$ factorial design experiment by finding sub-processes which relate to cycle time of the process. According to the simulation model, the line balancing condition creates the reduction to a process time, which is related to the cycle time of process and minimizing the cycle time from 306 seconds to 257 seconds without quality changing.

Keywords : Simulation model, Hard disk drive arm cleaning process

## 1 INTRODUCTION

The crucial final step of hard disk drive arm manufacturing is the hard disk drive arm cleaning process [1-2] before quality control procedure and delivery. The dust and particle are vulnerable to semiconductor production. Consequently, the hard disk drive arm cleaning process is important to remain the product quality. The company forecasted that the demand from customer will increase and exceed the current production capacity in the near future. To support more demand, the company has a determination to increase efficiency and capacity of production without effecting to the product quality.

Our research mainly focuses on the simulation model of hard disk drive arm cleaning machine created by ARENA software [3-4] to determine line balancing of process by using $2^k$ factorial design [5] in the simulation model. The relation is to find which sub-processes relate to the cycle time and using the flow process chart to find which step of sub-processes can be eliminated or reduce time. The present cycle time is 306 seconds and this research targets to determine a minimum cycle time that will not effect on the quality. If capacity is increased, the operation will gain more effectiveness including a particular process in production. The company also will have a capability to satisfy customers without adding a new machine for the increased demand in the future.

## 2 METHOD

### 2.1 Study hard disk drive arm cleaning process

The hard disk drive arm cleaning process uses an automatic machine, which works by robot arms to transfer products between sub-processes. Figure 1 describes the image of hard disk drive arm cleaning machine with the movement function of robot arms. Before the machine enabling, workers arrange products into the particular container, then load it into the machine and then robot arms pick up a container to each sub-process. This machine has 9 sub-processes and one station per sub-process except the eighth sub-process has two stations. The main task of the first

* Department of Industrial Engineering, Chiang Mai University

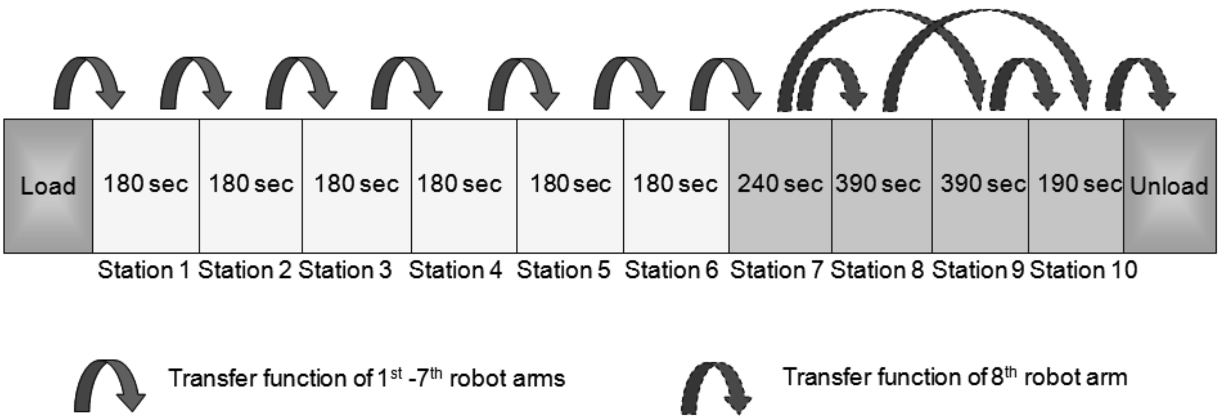


Fig. 1 Image of hard disk drive arm cleaning machine with the movement function of robot arms.

through sixth sub-processes is cleaning the product and the seventh through ninth sub-processes dry the product. The eighth sub-process has two stations for reducing a cycle time due to the longest operation time. Operation time of sub-processes is described in Table 1.

Table 1 Operation time of sub-processes in hard disk drive arm cleaning machine

| Sub-process | Station | Operation time (Second) |
|---|---|---|
| 1 | 1 | 180 |
| 2 | 2 | 180 |
| 3 | 3 | 180 |
| 4 | 4 | 180 |
| 5 | 5 | 180 |
| 6 | 6 | 180 |
| 7 | 7 | 240 |
| 8 | 8,9 | 390 |
| 9 | 10 | 190 |

For robot arms, this machine has 8 robot arms with a different movement function to transfer a container. It is described in Table 2. The first through seventh robot arms transfer a container between two stations but eighth robot arm transfers a container among five stations.

2.2 Create simulation model with ARENA software

The creation of simulation model with ARENA software can be concluded with 4 steps as follows:

(1) Set boundary of system. Range of this research initiates from a container loading into a machine to a finishing process and 8th robot arm transfers a container to the next process. The boundary primary concerns about effectiveness and production capacity from less cycle time.

(2) Create the simulation model. The model is developed by studying the mechanism and relative operation between sub-processes in the machine and then using ARENA software to create the simulation model. The mechanism and relative operation are pointed out as follows:

- Mechanism of each robot arm and sub-process in machine
- The relative operation of moving robot arm when pick up and don't pick up container.

(3) Data preparation. The data collection concentrates on the operation time relating to all processes. After that, the collected data will be used to determine a proper distribution form of data by analysis of ARENA software and add them into the simulation model. The operation time is classified as follows:

- Cleaning and drying product time of each sub-process.
- Robot arms moving time when pick up and don't pick up container.

Table 2 Movement function of robot arms to transfer container

| Robot arm | Transfer container | |
|---|---|---|
| | From station | To station |
| 1 | Load | Station 1 |
| 2 | Station 1 | Station 2 |
| 3 | Station 2 | Station 3 |
| 4 | Station 3 | Station 4 |
| 5 | Station 4 | Station 5 |
| 6 | Station 5 | Station 6 |
| 7 | Station 6 | Station 7 |
| 8 | Station 7 | Station 8 or 9 |
| | Station 8 or 9 | Station 10 |
| | Station 10 | Unload |

(4) Test the accuracy of the simulation model. The test uses comparison of results between the simulation model and actual situation. This research uses a cycle time as a primary result for testing accuracy.

Figure 2 show simulation model of process with ARENA software. After the simulation model was developed and filled distribution form of all operation time into the simulation model, the test compared a cycle time between the actual situation and the simulation model as describes in Table 3 (n=15). The data shows no significance different at the 0.05 level of testing by two samples t-test so the simulation model is reliable for the problem analysis and solving.

Table 3 Comparison of cycle time between actual situation and the simulation model

| Data | Actual situation (Second) | Simulation model (Second) | Percent of difference (%) |
|---|---|---|---|
| Max | 311 | 306.01 | 1.60 |
| Average | 306 | 305.95 | 0.02 |
| Min | 301 | 305.90 | -1.62 |

2.3 Analyze simulation model

After brain storming with engineers of the company, some sub-processes use excessive operation time and have a possibility to reduce. Therefore, the analysis determines which sub-process has effect on cycle time (when an operation time is reduced, a cycle time is reduced). Technique of this research is the experimentation $2^k$ factorial design in the simulation model [6-7]. This technique has been popularly used by previous researchers to simulate and analyze before applying to the actual situation. This research uses a cycle time be a result of experiment. Sub-processes that were used in the experiment include four sub-processes as follows:

- $6^{th}$ sub-process
- $7^{th}$ sub-process
- $8^{th}$ sub-process
- $9^{th}$ sub-process

Next, the experiment was determined a level of each sub-process by using an experience from the company's engineer. The experiment design and the experiment response are described in Table 4.

The experiment was analyzed the result by MINITAB software for determining which sub-processes have an effect on a cycle time. The analyzed result could be explained by normal probability plot of effect (see Figure 3). In conclusion, the $6^{th}$ sub-process (A), $7^{th}$ sub-process (B), $9^{th}$ sub-process (D) and the combined effect between the $6^{th}$, $7^{th}$ and $9^{th}$ sub-process had the effect on the cycle time. The next step was determining line balancing condition of the process for reducing a cycle time.

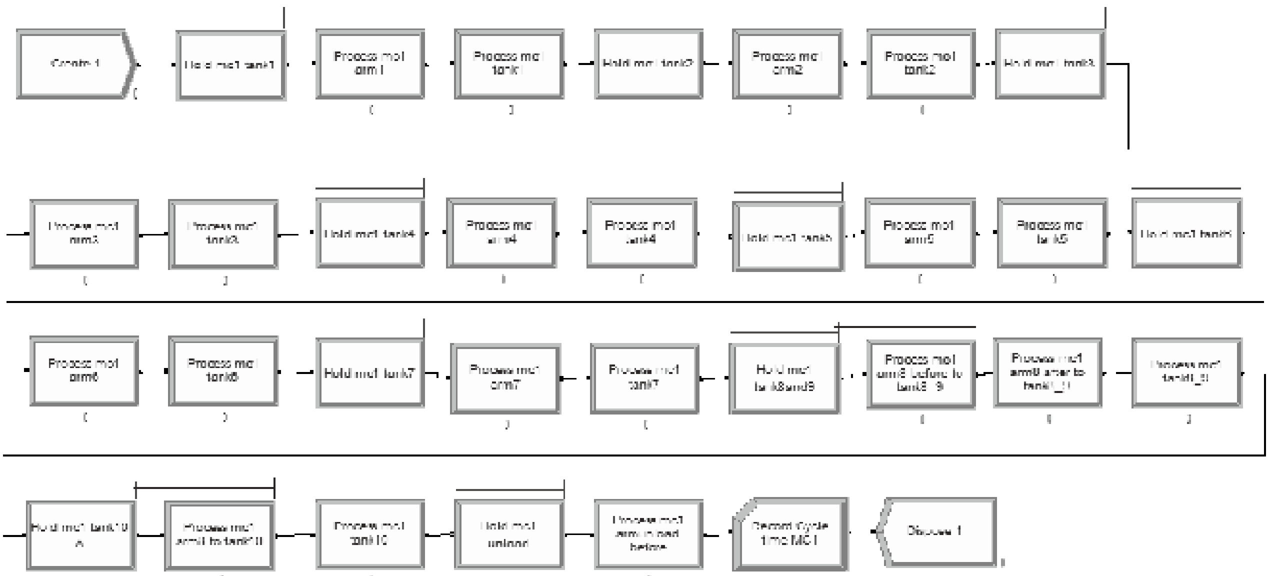

Fig. 2 Simulation model of hard disk drive arm cleaning process with ARENA software

Table 4 The experiment design and the experiment response

| No. | $6^{th}$ Sub-process (A) | $7^{th}$ Sub-process (B) | $8^{th}$ Sub-process (C) | $9^{th}$ Sub-process (D) | Cycle time (Second) |
|---|---|---|---|---|---|
| 1 | 150 | 180 | 360 | 160 | 270.91 |
| 2 | 180 | 180 | 360 | 160 | 300.89 |
| 3 | 150 | 240 | 360 | 160 | 305.03 |
| 4 | 180 | 240 | 360 | 160 | 305.03 |
| 5 | 150 | 180 | 390 | 160 | 270.91 |
| 6 | 180 | 180 | 390 | 160 | 300.85 |
| 7 | 150 | 240 | 390 | 160 | 305.92 |
| 8 | 180 | 240 | 390 | 160 | 305.92 |
| 9 | 150 | 180 | 360 | 190 | 285.80 |
| 10 | 180 | 180 | 360 | 190 | 300.88 |
| 11 | 150 | 240 | 360 | 190 | 305.80 |
| 12 | 180 | 240 | 360 | 190 | 305.66 |
| 13 | 150 | 180 | 390 | 190 | 285.80 |
| 14 | 180 | 180 | 390 | 190 | 300.85 |
| 15 | 150 | 240 | 390 | 190 | 305.92 |
| 16 | 180 | 240 | 390 | 190 | 305.92 |

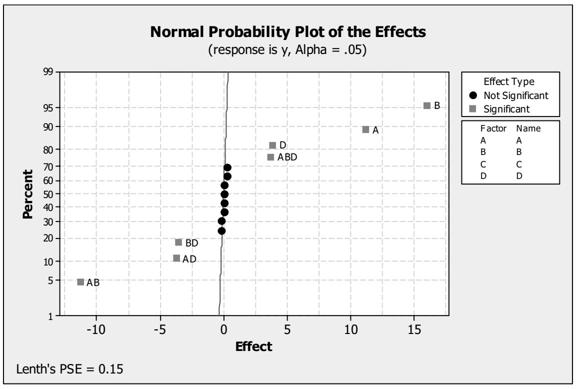


Fig. 3 Normal probability plot of effect from experiment

2.4 Determine line balancing condition

The flow process chart [8] of $6^{th}$, $7^{th}$ and $9^{th}$ sub-processes were created for determining line balancing (see Figure 4-6).

According to Figure 4, some steps including the $3^{rd}$ and $4^{th}$ steps consist of idle time that causes a delay. $3^{rd}$ step cannot be improved because the function related to the machine software, which needed a programmer from a vendor to modify it with extra cost so the company did not choose this option to save an expense. $4^{th}$ step directly relates to an operation time of $7^{th}$ sub-process. If the operation time of $7^{th}$ sub-process is decreased by 5 seconds, it'll eliminate idle time in $4^{th}$ step of $6^{th}$ sub-process and make the cycle time of $6^{th}$ and $7^{th}$ sub-processes are same at 301 seconds.

| Step No. | Detail | Symbol | Time (Second) |
|---|---|---|---|
| 1 | Clean product | ●⇨□D | 180 |
| 2 | $7^{th}$ robot arm picks up container in $6^{th}$ sub-process | ○➡□D | 71 |
| 3 | Wait $1^{st}$ robot arm picks up container in load station | ○⇨□◗ | 32 |
| 4 | Wait $8^{th}$ robot arm transfers container from $7^{th}$ to $8^{th}$ sub-process | ○⇨□◗ | 5 |
| 5 | $6^{th}$ robot arm transfers container to $6^{th}$ sub-process and starts cleaning again | ○➡□D | 18 |

Fig. 4 Flow process chart of $6^{th}$ sub-process

| Step No. | Detail | Symbol | Time (Second) |
|---|---|---|---|
| 1 | Dry product | ●⇨□D | 240 |
| 2 | $8^{th}$ robot arm picks up container in $7^{th}$ sub-process and transfers to $8^{th}$ sub-process | ○➡□D | 34 |
| 3 | $7^{th}$ robot arm transfers container to $7^{th}$ sub-process and starts drying again | ○➡□D | 32 |

Fig. 5 Flow process chart of $7^{th}$ sub-process

| Step No. | Detail | Symbol | Time (Second) |
|---|---|---|---|
| 1 | Dry product | ● ⇨ □ D | 190 |
| 2 | 8th robot arm picks up container in 9th sub-process and transfers to unload station | ○ ➡ □ D | 50 |
| 3 | Wait 8th sub-process dry finish | ○ ⇨ □ ◗ | 20 |
| 4 | 8th robot arm pick up container in 8th sub-process and transfer to 9th sub-process and start drying again | ○ ➡ □ D | 46 |

Fig. 6 Flow process chart of 9th sub-process

According to Figure 5, there is not idle time in steps so the cycle time reduction can solely make in the 7th sub-process, which is drying time in 1st step because 2nd and 3rd steps depend on a speed of robot arms that cannot increase more speed.

Figure 6 represent that there is idle time occurring in 3rd step. This step relates with an operation time of 7th sub-process. If the process decreases an operation time of 7th sub-process by 20 seconds, the 3rd step of 9th sub-process will be eliminated and make the cycle time of 7th and 9th sub-processes equal to 286 seconds.

Concluding, this process can make line balancing by reducing the operation time of 6th sub-process for 15 seconds and the 7th sub-process for 20 seconds. The new cycle time is 286 seconds. Moreover, if the operation time of 6th, 7th and 9th sub-processes is reduced, the cycle time will be reduced too.

### 2.5 Minimize a cycle time

After determining the line balancing condition, the next task is determining how to reduce the operation time of 6th, 7th and 9th sub-process without effect on the product quality.

According to Figure 4, the 2nd step, which equips the 7th robot arms for picking up a container during the 6th sub-process, uses an operation time 71 seconds that is the longest time of robot arms spending for picking up a container. This step obviously needs to increase an operation speed. After speed boosting, an operation time was reduced from 71 to 19 seconds or overall of operation time in the 6th sub-process was reduced 52 seconds. In order to create line balancing, the 7th sub-process must be reduced an operation time for 57 seconds and the 9th sub-process must be reduced an operation time for 37 seconds.

From Figure 5 and 6, the operation time can solely be reduced at the 7th and 9th sub-process by decreasing the drying time because the other steps were depending on a speed of robot arms, which currently reach the maximum speed. The drying time of 7th sub-process must be reduced for 57 seconds and 9th sub-process must be reduced for 37 seconds. For convenience of engineers and workers to perform the maintenance and performance condition checking, company's engineers chose to decrease the drying time of 7th sub-process for 60 seconds and 9th sub-process for 30 seconds. Then, the new condition was used in the simulation model to confirm a result. The new cycle time was about 257 seconds approving an improvement of the condition for using in the actual situation.

After applying the new condition, the actual cycle time was reduced exactly to 257 seconds and the product quality did not change including regulation pass that particles must be lower than 80,000 particles per cm2. Table 5 shows a comparison of particle quantity size 0.3 µm per $cm^2$ on a product before and after improvement. The data shows no significance different at the 0.05 level of testing by two samples t-test.

Table 5 Comparison quantity of particle size 0.3 µm per $cm^2$ on product between before and after improvement

| Data | Before | After |
|---|---|---|
| Average | 11,835 | 13,948 |
| SD | 2,846 | 5,033 |
| Max | 19,228 | 27,015 |
| Min | 6,082 | 6,138 |

## 3 CONCLUSION

The aim of this paper is to reduce a cycle time of the hard disk drive arm cleaning process to support the growth of demand in the future without effect on the product quality by using the simulation model and $2^k$ factorial design experiment. After improvement, the cycle time of process was reduced from 306 seconds to 257 seconds. In another word, the company gains more capacity from 26,470 to 31,517 pieces per day and this improvement did not pay an extra expense.

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