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Manufacturing Process Cost Reduction of Agricultural Machinery Part

Ramidayu Yousuk[1,a] and Thidarat Rangsiearam[2]

[1,2]Department of Industrial Engineering, Kasetsart University, Bangkok, Thailand

aCorresponding author's e-mail address: ramidayu.y@ku.th

Abstract. Company ABC is an agricultural machinery part manufacturer. Nowadays demand of such parts are substantially increasing. Cost reduction without affecting product quality become a proper way to raise organization profit. Prior study of manufacturing process of part A shows that the processing cost is too high as a result from short tool life, non-value-added movement of tools, high loading and unloading time, improper number of operator which effect the labour utilization and cost. This project mainly focuses on reducing processing cost by rectifying the problem mentioned above. The improvement includes experimenting to locate the appropriate cutting factors resulted in longer tool life. The shape of drill is changed in order to lengthen tool life. Loading and unloading time is decreased by using the new design of clamp. The movement of cutting tool in machining centre is redesigned and lastly man-machine chart is employed to enhance the labour utilization. As a result, the objective of this project is reached. The processing cost of Part A is decreased from 21.78 Baht to 19.55 Baht or 2.23 Baht which is 10.24% and cycle time also shortens. The proper number of operator is now decreased from 3 operators to 2 operators.

1. Introduction

Nowadays, automotive and agricultural machinery sector are rapidly growing industry among others. This results in high demand of raw material and machinery parts. Entrepreneurs in these industry section are under pressure to produce trifecta products which are high quality, on time delivery and lastly competitive price. In order to lower the price than that offered by the competitors, the production cost is needed to be substantially decreased without affecting product quality. This is the intuition behind this study. Production cost mainly consists of raw material cost, labour cost and overhead cost. One proper way to reduce the production cost and to create competitive advantage is to improve the manufacturing process using engineering techniques and tools such as waste reduction, labour utilization, material selection, and proper tool setting. Prior study of manufacturing process of part A shows that the processing cost is too high as a result from short tool life, non-value-added movement of tools, high loading and unloading time, improper number of operator which effect the labour utilization and cost. These are the seven wastes of lean manufacturing. This paper proposed the application of industrial engineering techniques such as ECRS (eliminate-combine-rearrange-simplify), man-machine chart, redesign of jig and fixture to decrease those 7 wastes which will improve the productivity of manufacturing process. That results in the production cost reduction of Part A at the case study company.

The 7 wastes of lean manufacturing concept is common issue that manufacturing companies face today. It consists with overproduction, waiting, transporting, inappropriate processing, unnecessary Inventory, excess motion, and defects. Many study has been attempt to reduce those wastes. Some of the recent research has been summarized as follow. In [1], the cost reduction was attempted using

operations reversal. The results were promising in some case and highly depend on cost parameters and lead times on operations reversal under the cost measure. [2] presented the design and development of a sequence of activities that emphasizes the application of simulation capabilities as a tool to aid the continuous improvement process. A new framework that allows continuous improvement for the reliability of production process and product throughput was presented in [3]. This new framework allows engineers with less effort to define and measure failures of production processes and it includes techniques like Six Sigma DMAIC, FMEA, TOC, FC, swim-line diagram. [4] attempted to reduce the process variation by standardization. It is a powerful tool in improving the organization. Due to space limitation, the detailed of more related work is impossible to present here. However there are many study in this field such as [5,6]. Even though there are different method and concept used in [1-6], the results have led to the process cost reduction. This paper will also focus on reducing the process cost but with different techniques.
ECRS is one of the motion study technique used to improve production lines. It focuses on eliminate unnecessary work, combine operations, rearrange sequence of operations and simplify the necessary operations. In this study, the concept of combine and rearrange will be used in section 4 and 5.
The remaining parts of this paper are organized as follows. Section 2 presents the past research and related work in this field. Section 3 explains the problem description, the manufacturing process and cost analysis of Part A. The cost reduction techniques used in this paper is presented and explains in section 4. Comparative numerical results are also exhibited in this section. Finally, the conclusions are drawn and presented in Section 5 along with future research directions.

2. Problem description

Company ABC produces various kind of agricultural machinery parts. This study mainly focuses only product A which has the total cost of 119.99 baht/piece. The cost structure of product A is shown in Table 1.

Table 1. Cost Structure of Product A.

Cost	Baht	Percentage
Material Cost	77.00	64.17
Process cost	21.78	18.15
Reject cost	2.96	2.47
Administration cost	10.17	8.48
Investment cost	8.07	6.73
Total	119.99	100.00

As shown in Table 1, material cost is the major cost of product A, however, this cost come from the supplier. Therefore, only the process cost is the subject of interest. The objective of company ABC is to reduce the process cost by at least 7% via the improvement of the product A manufacturing process. The process of making product A is divided into 4 operations. As shown in Figure 1, the process cost of operation 1 and 2 is 80.12% of the total process cost. It is worth mentioned that operation 1 and 2 take place in a machining centre with several work elements. Figure 2 shows the process cost of each element in operation 1 and 2.

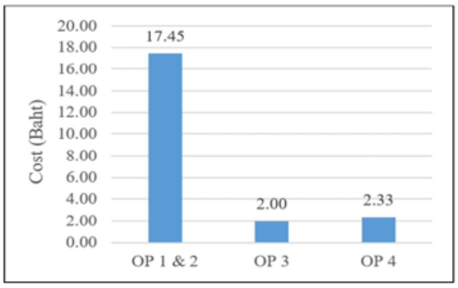

Figure 1. The process cost of each operation in the making of product A.

Figure 2 shows that rough facing Ø80 mm., finish facing Ø100 mm., and drilling Ø7mm. are the elements with highest process cost. Table 2 presents the process time for each element. Load and unload operation take longer time compared to most work elements. The improvement of process which lead to reduction in process cost is divided into 4 phases,

1. The cutting condition is studied in order to increase tool life or decrease process time.
2. Clamp is designed to improve and reduce the time of the load and unload activity.
3. The transportation waste of tool in Facing Ø80 mm. rough and Facing Ø100 mm. finish are studied and decreased.
4. The waiting waste of operators is studied and decreased.

Table 2. The process time of each element

Operation	Process	Cycle time (sec)	Total time (sec)
Operation 1	Load	29.0	97.5
	Facing Ø80 mm. Rough	17.5	
	Facing Ø100 mm. Finish	17.5	
	Drilling Ø7 mm.	33.5	
Operation 2	Spot facing	6.5	74.5
	Drilling Ø6.8 mm.	7.5	
	Drilling Ø5.0 mm.	5.5	
	Chamfer	8.0	
	Tapping M8x1.25	17.0	
	Tapping M6x1.0	12.0	
	Unload	18.0	
Operation 3	Load	16.0	61.4
	Peeling	32.4	
	Unload	13.0	
Operation 3	Cleaning and Checking	170.1	170.1
	Total		403.5

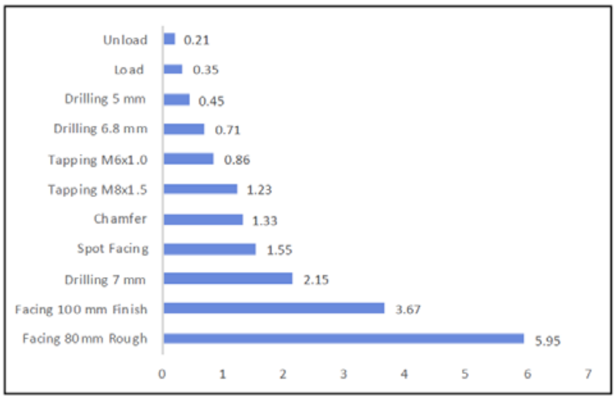

Figure 2. The process cost of each element in operation 1 and 2

3. Improve of cutting condition

Cutting tool cost is one of the major part in process cost [7], in this section, the proper cutting condition is determined in order to extend the tool life which then decrease tool cost. The intuition is that if the company replace the cutting tool too soon it will result in high cutting tool cost. On the contrary, if the cutting tool is not replaced on time, this can cause a process breakdown or defects

which can increase labour cost or reject cost. The objective in this section is to lengthen the tool life by determined the appropriate level of cutting factors.
As mention earlier, this study focus only the first three elements with highest process cost which are rough facing Ø80 mm., finish facing Ø100 mm., and drilling Ø7mm. The cutting factors that affect the tool life in these process are cutting speed (m./min.) and feed rate (mm./min.). The experiments are conducted by setting vary the value of cutting speed and feed rate in order to find the optimum cutting condition. The results are summarized in Table 3.

Table 3. The optimum cutting condition

No.	Work Element	Cutting speed (m./min.)	Feed rate (mm./min.)	Tool life (pieces)	
				Before	After
1	Facing Ø80 mm. Rough	120.00	0.20	330	330
2	Facing Ø100 mm. Finish	310.00	0.13	800	720
3	Drilling Ø7 mm.	156.00	1.32	2,000	3,326

As shown in table 3, the tool life is increased for rough facing Ø80 mm., and drilling Ø7mm. but is decreased for finish facing Ø100 mm. However, with the new cutting condition, the process time and the process cost are decreased as shown in Figure 3 and 4.

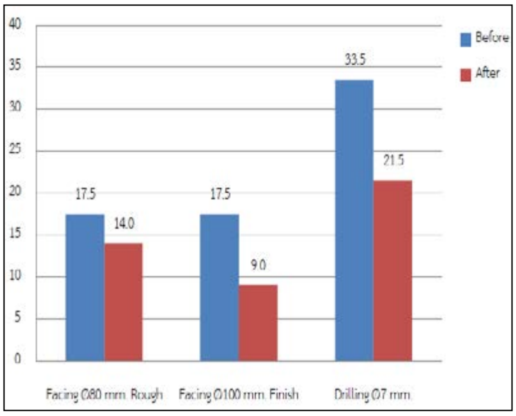

Figure 3. Comparison of the process time (sec.)

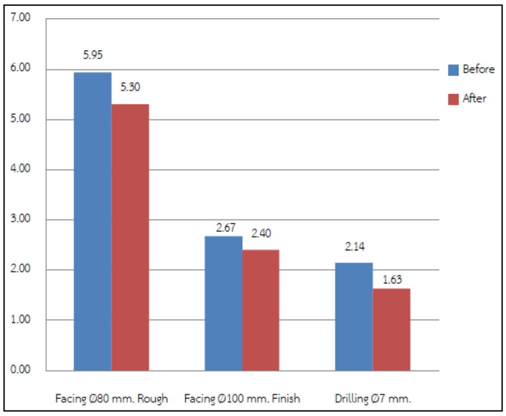

Figure 4. Comparison of the process cost (Baht)

4. Improvement of load and unload activity

Operation 1 and 2 take place in the same machining center. Both operations require clamps to hold the work in a fixed location while the cutting tool operates. Figure 5 demonstrates the location of clamps in operation 1.

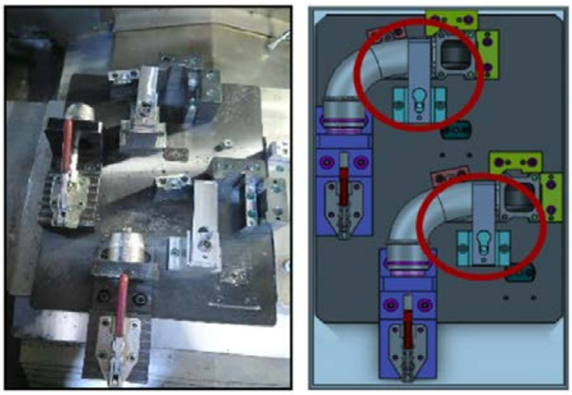

Figure 5. Location of clamps in operation 1

As shown in Figure 5, two clamps are required in this operation. This results in excessive motion and time in the load and unload activity. The ECRS concept was employed. In the old design, the operator need to operate on the clamps twice each time. The new clamp is designed using SolidWorks in order to improved productivity and reduced time [3]. Figure 6 shows this new clamp and how to use in the machining center. With this new design clamp, the motion has been reduced in half from previous clamp.

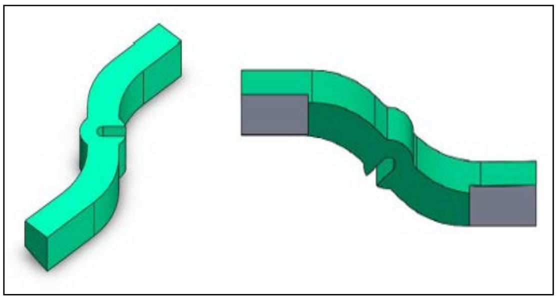

Figure 6. The design of new clamp

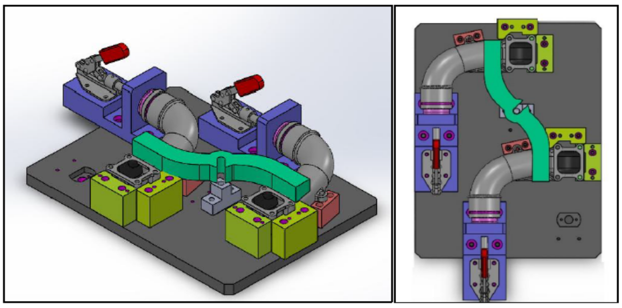

Figure 7. The new clamps in machining center

As shown in Figure 7, by using the new clamp, it combines and simplify load and unload activity which leads to reduction in motion and time. The results of this experiment is are shown in Table 4. It is shown that the time for load and unload activity has been reduced, hence the reduction in process cost. It is worth mentioned that the cost of new clamp is not considered in this study. The material for this new clamp come from the recycle material in the factory.

Table 4. The time and process cost of each element

No.	Work Element	Time (sec.)		Process Cost (Baht)		
		Before	After	Before	After	Diff
1	Load	29.00	22.00	0.35	0.26	0.09
2	Unload	18.00	14.00	0.21	0.17	0.04
	Total	47.00	36.00	0.56	0.43	0.13

5. Improvement of transportation waste

In this section, the cutting tool movements of rough facing Ø80 mm. process and finish facing Ø100 mm. process are analyzed. The result shows many unnecessary moves thus the direction of the cutting tool is redesigned to eliminate these transportation wastes. The concept of rearrange sequence of operations was employed. Figure 8 and 9 demonstrate the cutting tool direction of rough facing Ø80 mm. process before and after the improvement. The improvement result is shown in Table 5. The similar technique is cloned to finish facing Ø100 mm. process. The improvement result is summarized in Figure 10 and Table 6.

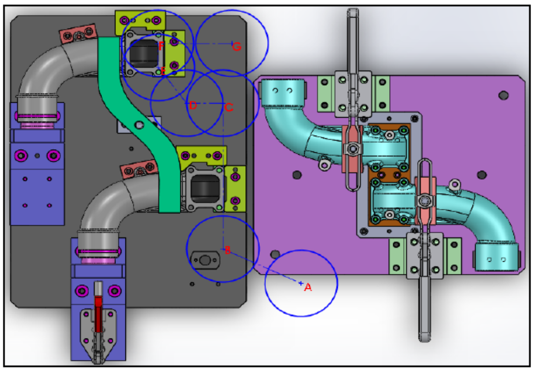

Figure 8. The direction of cutting tool before improvement in rough facing Ø80 mm. process

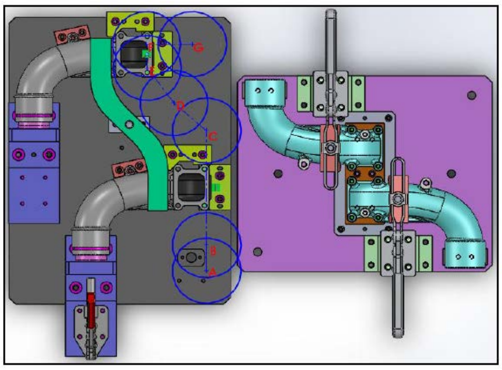

Figure 9. The redesign direction of cutting tool in rough facing Ø80 mm. process

Table 5. Improvement in rough facing Ø80 mm. process

Point	Distance (mm.)		Cycle Time* (Sec.)	
	Before	After	Before	After
A-B	33.00	15.00	0.07	0.03
B-C	34.00	25.50	3.40	3.07
C-D	30.50	15.00	0.07	0.03
D-E	17.75	12.25	1.78	1.48
E-F	14.75	10.00	1.48	1.20
F-G	19.75	9.75	1.98	1.17
Total	149.75	87.50	8.76	6.99

*It is noted that the cycle time depends on distance and table feed.

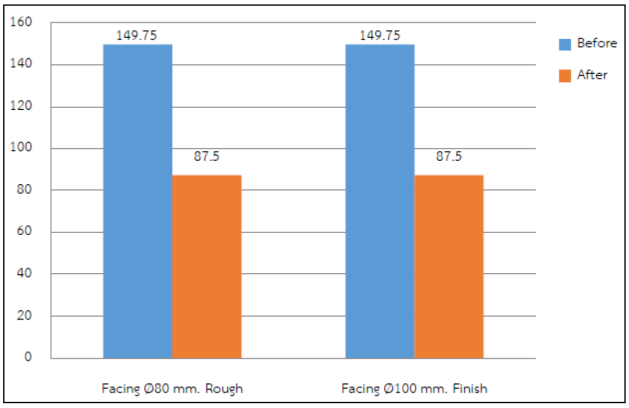

Figure 10. The travel distance reduction of the cutting tool (mm.)

Table 6. The improvement in process cost of each element

No.	Work Element	Time (sec.)		Process Cost (Baht)		
		Before	After	Before	After	Diff
1	Facing Ø80 mm. Rough	8.76	6.99	5.30	5.21	0.09
2	Facing Ø100 mm. Finish	8.76	4.54	2.41	2.18	0.23
					Total	0.32

6. Improvement of waiting waste

The operator in operation 1 and 2 has unnecessary waiting time. Man-machine chart is conducted to confirm this problem. This chart is employed to exemplify the most productive way to use multiple operators, machines or any combination of people and machines [4]. The result is shown in Table 7.

Table 7. Utilization of the operator and machining center in operation 1 and 2

	Operator	Machining center
Idle time (sec.)	80.00	36.00
Working time (sec.)	51.00	95.00
Total time (sec.)	131.00	131.00
Utilization (%)	38.93	72.52

Similar analysis is conduct for operation 3, the result is shown in Table 8.

Table 8. Utilization of the operator and lathe machine in operation 3

	Operator	Lathe machine
Idle time (sec.)	24.40	29.00
Working time (sec.)	37.00	32.40
Total time (sec.)	61.40	61.40
Utilization (%)	60.26	52.77

From the results discussed above, the improvement is proposed. Only one operator is needed to operate both machining center and lathe machine. (One operator for operation 1, 2 and 3) The utilization of the operator and lathe machine after this improvement is demonstrated in Table 9.

Table 9. Utilization of the operator and lathe machine in operation 3

	Operator	Machining center	Lathe machine
Idle time (sec.)	16.40	46.40	92.60
Working time (sec.)	125.00	95.00	48.80
Total time (sec.)	141.40	141.40	141.40
Utilization (%)	88.40	67.19	34.51

The improvement from this improvement is shown in Table 10.

Table 10. Comparison of process time and cost between 1 and 2 operators

No. of operator	Process time of operation 1, 2, and 3 (sec.)	Process Cost (Baht)
2	192.41	17.57
1	141.40	17.22
Difference	51.01	0.35

From the improvement in section 3-6, the process cost reduction in each section is presented in Figure 11.

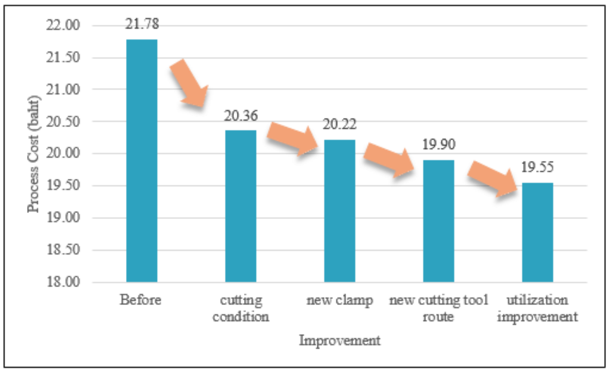

Figure 11. Reduction of process cost

7. Conclusion

This study aims to reduce process cost of agricultural machinery part. Various techniques is employed to improve a manufacturing process such as better cutting tool condition, design of fixture to help eliminate unnecessary motion, the redesign of cutting tool route in machining centre. The result shows the reduction of process cost from 21.78 Baht to 19.55 Baht or 10.24% reduction which is better than the company expectation. The future work should be focused on other work elements in manufacturing process. Some techniques such as simulation, motion economy etc. may be considered.

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