CHAPTER 4

LINE BALANCING LOSSES

This chapter focusing on operation time between man and machine. Company's manufacturing type is cell manufacturing which operators and machine must operate together. Working time of man and machine must be balanced to reduce idle time.

4.1 Analyze cause of operation loss.

Cause of operation losses compose of

1. Manual operation.
   Manual operation is all operation which done by operator. Such as load/ unload work into jig and push start button to start machine operation.
2. Machine operation.
   Machine operation is the operation after operator push start button and machine operate alone.

4.2 Process analyzing method

Man-machine chart is a tool for analyzing operation time. This method used for identifies whether manual operation or machine operation will be improved. Method for analyze process will be explained in Appendix E.

4.3 Method for improve operation

Method of improvement can be defined into 2 items, as shown in figure 4.1

1. Improve manual operation
   If all manual working time is longer than bottleneck machine the improvement must be done by reduce manual time. It can be reduced by
   1. Increase operator. If number of operator increased, operation time per person will be decreased.
   2. Improve load/unload system. Such as install injector at jig when machine finish working ejector will push work form jig.
   3. Improve motion by reduction of waste motion.

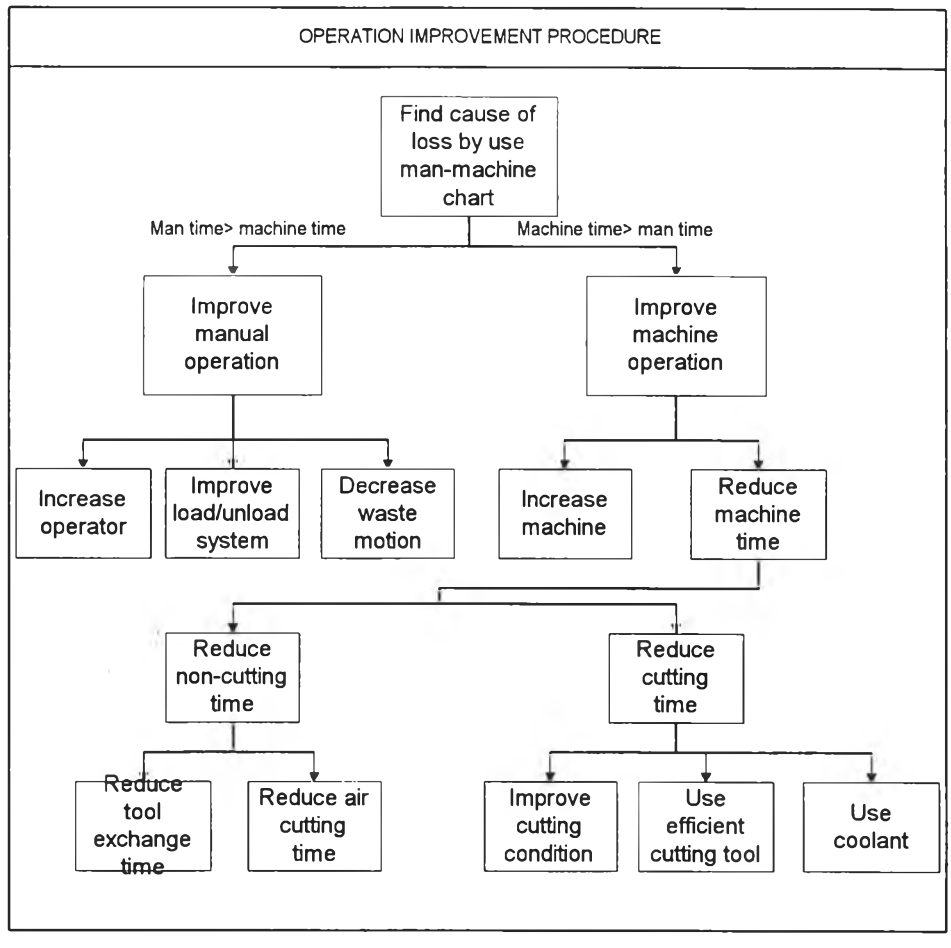


Figure4.1 Operation improvement procedure

2. Improve machine operation.

   In case of the bottleneck operation are longer than total manual time, time of bottleneck machine should be reduced. The method for reduction can be classified into 2 main categories

   1. Increase number of machine. By increasing the machine which performs the same process as bottleneck machine. The standard time of bottleneck will be reduced.
   2. Reduce machine time. This is the easiest method to improve machine operation because of low investment. So, this method would be firstly applied. The method for reduce machine time are as follow

- Reduce non-cutting time

This type of reduction will not affect to the quality of product and tool life. Concerning items for reduction non- cutting time compose of

1. ATC (Automatic tool change) or AWC (Automatic work changer).
2. Reduction of tool exchange time
3. Reduction of air cutting time. Air cut time refers to all cutting length, which not added value to the product. Air cutting time compose of safety length and overtravel length.

- Safety length and Overtravel length

Safety length (as shown in figure 4.2) is necessary for any stock variations in length. Because if the cutter is in rapid-traverse velocity and the trip that cancels the fast mode to table or cutter movements are set too short, it is possible for the cutter to collide into the workpiece. If safety length is too long, it will take unnecessarily longer time for cutting.

Safety length or R point in CNC machine that refers to Z value when cutting is started in cutting feed in the fixed cycle mode. Normally the value of 2 to 3 mm (5-7 cm for tap cycle) from the machined top surface is set. (Reference: OKK programming manual, 1996)

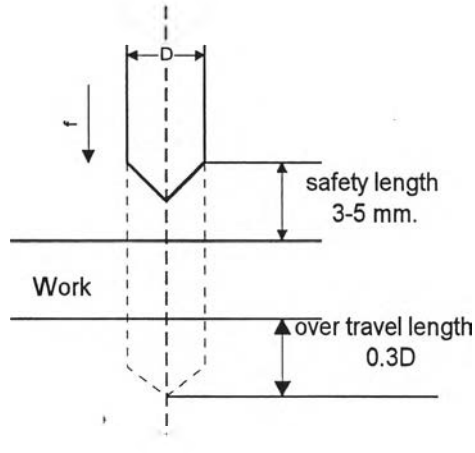


Figure 4.2 Total cutting length

2. Reduce cutting time

This type of reduction considered the quality of product and tool life. High efficiency of cutting such as high-speed cutting, high feed cutting, depth of cut should be concerned.

But cost variables depend on cutting speed. For example, as cutting speed increased machining time for a particular workpiece decreased. However, tool life generally decreases with cutting speed.

1. Using efficient tool for high cutting speed. Various cutting tool material having a wide range of properties are available. Proper selection of tooling is a critical factor in quality of work and economics of machining. For example of tool material, diamond tool better than carbide tool and carbide tool is better than high-speed tool.
2. Improvement chip control by best chip breaker selection.
3. Using of cutting fluid can reduce problem from heat and friction when cutting with high speed.

4.4 Analyze operation loss of sample line.

Refer to improvement procedure in figure 4.1, data of machine time and manual time were collected. Table 4.1 is a working time of each machine. Table 4.2 is a manual time for each process.

- Data collection

1. Machining time.

Table 4.1 machine time of line M05

Process No.	Machine name	T2
1	Multi drilling machine	1.36
2	OKK vertical machining center	7.33
2	OKK vertical machining center	7.33
3	Tapping machine	0.26
4.	Drilling machine	0.75
5	Press machine	0.12
6.	Jig	
7.	ENSHU machining center	3.68
8.	OKK vertical machining center	4.3
9.	Jig	
10.	Washing machine	2.1
11.	Jig	
12.	Leak checker	1.43
13.	Air blower	1.6

2. Operation time

Table 4.2 Manual operation time of line M05

Process	Start point	Finish point	Average T1
1.	Pick up R/M form rack	Push start bottom of M/C1	0.1
2.	Push start bottom of M/C1	Push start bottom of M/C2	0.53
3.	Push start bottom of M/C2	Push start bottom of M/C3	0.3
4.	Push start bottom of M/C3	Push start bottom of M/C4	0.1
5.	Push start bottom of M/C4	Push start bottom of M/C5	0.2
6.	Push start bottom of M/C5	Assembly cover with O/P	0.35
7.	Assembly cover with O/P	Push start bottom of M/C7	0.21
8.	Push start bottom of M/C7	Push start bottom of M/C8	0.25
9.	Push start bottom of M/C8	Unload work form jig	0.37
10.	Pick up work form jig	Push start bottom of M/C7	0.1
11.	Push start bottom of M/C7	Unload work form jig	0.17
12.	Unload work form jig	Push start bottom of leak checker	0.4
13.	Push start bottom of leak checker	Pick up R/M form rack	0.4

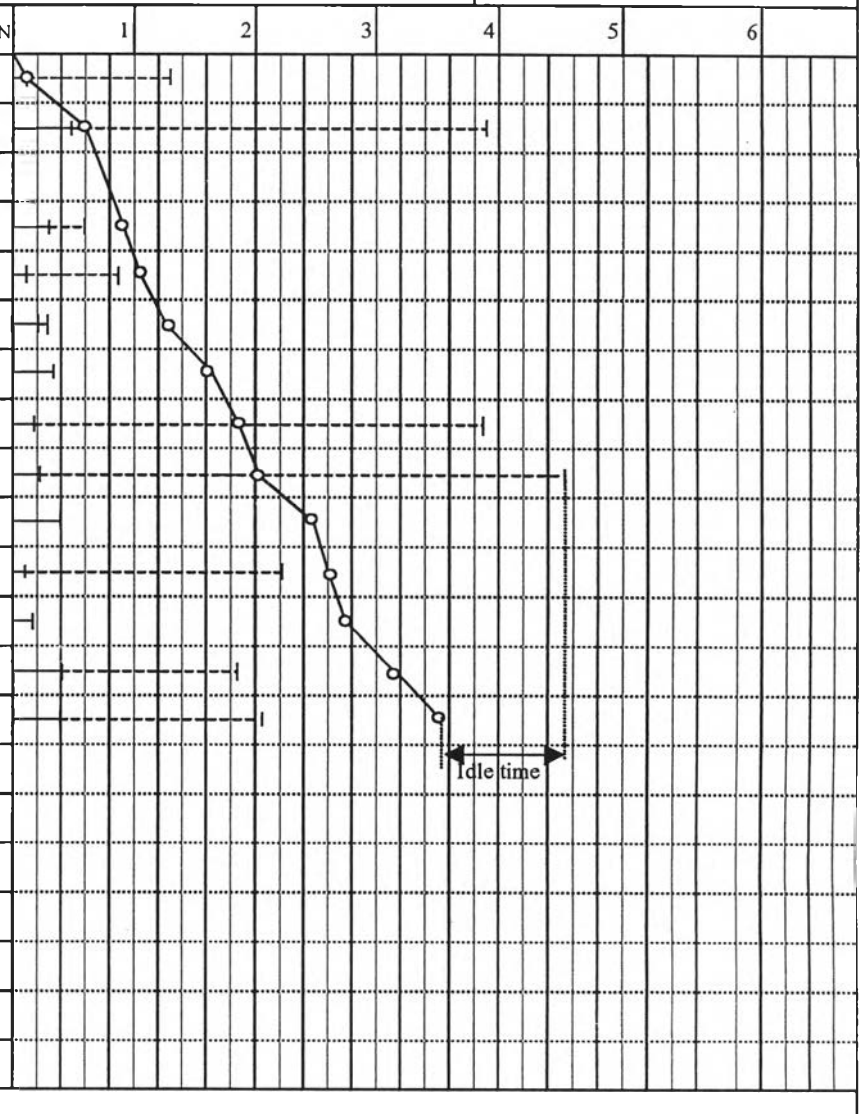
3. Fill data and draw chart in man-machine chart. Result of Line M05 is in table 4.3.

Man-machine chart indicated that the longest operation time is machine process9 which take 4.55 minute and the manual operation time is 3.48 minutes. Cycle time for produce 1 piece of product is 4.55 minutes. The difference between the longest machining time and total manual time is idle time. In table 4.3, gap between longest machine time and total manual time is idle time. For this sample line, idle time is 4.55-3.48 = 1.07 minutes. To balancing line, the time of each process and total manual time must be equally. Manual operation time will be set as a target time for improvement.

Table 4.3 Analyze data of man-machine time in line M05

WORK NAME FRONT CASE	MAN-MACHINE CHART	Y	M	D	T1: OPERATING TIME
LINE M05					T2: MACHINE TIME
					T3: IDLE TIME

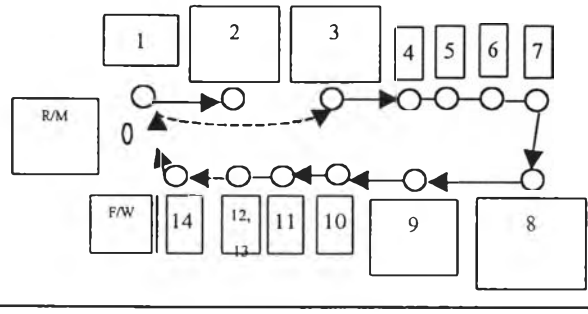
No	PROCESS	T1	T2	T	MAN
1	DRILL OIL DRAIN	0.10	1.36	1.46	
2	ROTOR MACHINE	0.53	6.80	7.33	
3	ROTOR MACHINE	0.53	6.8	7.33	
4	TAP PT 3/8	0.3	0.26	0.56	
5	DRILL DIA 9	0.1	0.75	0.85	
6	PRESS PIN	0.2	0.12	0.32	
7	SET BOLT&COVER	0.35		0.35	
8	2-SIDE MACHINE	0.21	3.68	3.89	
9	VALVE HOLE	0.25	4.3	4.55	
10	SET BOLT&COVER	0.37		0.37	
11	WASH	0.1	2.1	2.20	
12	UNASS'Y BOLT	0.17		0.17	
13	CHECK LEAK	0.4	1.43	1.83	
14	AIR BLOW	0.4	1.6	2.00	
total T1		3.48			



T(MAX) 4.55

SUM T1 3.48

LINE LAYOUT



4.5 Improvement plan

There were 4 processes which machine time and manual time are higher than 3.86 minutes, i.e., process 2,3,8 and 9. Man-machine chart shows idle time occur in process 9 (Valve hole). This process was the bottleneck of machining operation. Target of improvement is to reduce idle time of machine until less than total manual time. In this case, operation 9's time must be reduced from 4.55 to less than 3.48 minute.

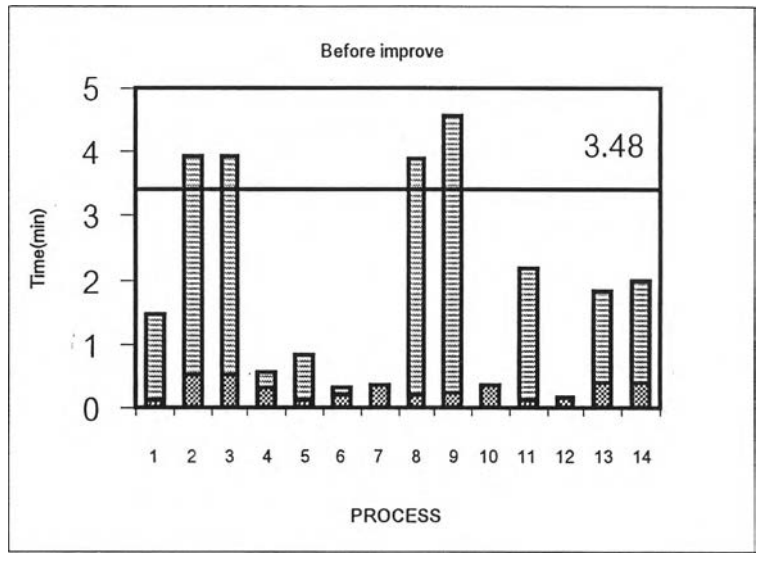


Figure 4.3 time chart before improvement

Figure 4.3 shows the operation time for each process. Each column compose of 2 parts lower column is manual operation time, the other is machining operation. Total manual time will be set as target time to reduce idle time of manual operation.

4.6 Improvement item.

1. Reduction of non-cutting time.

- Reduce of air cut time

Study current condition. Reduce cutting approach for each tool. R point in table 4.4 is the length from tool tip to cutting surface.

- Data collection for safety length reduction

Table 4.4-safety length from cutting surface.

Tool name	Safety point (R point) (mm.)		
	Before	After	Reduce
Rough reamer diameter 14.8	5	-	0
Burnishing reamer diameter 15	5	-10	15
Spot facing diameter 25	5	-	0
TAP M18	3	-	0
Face milling diameter 80	15	5	10
TAP M6(4 point)	3	-	0
TAP M18(2 point)	3	-	0

Improvement point.

1. Burnishing reamer diameter 15. Figure 4.4 shows the reduction of R point of burnishing tool .

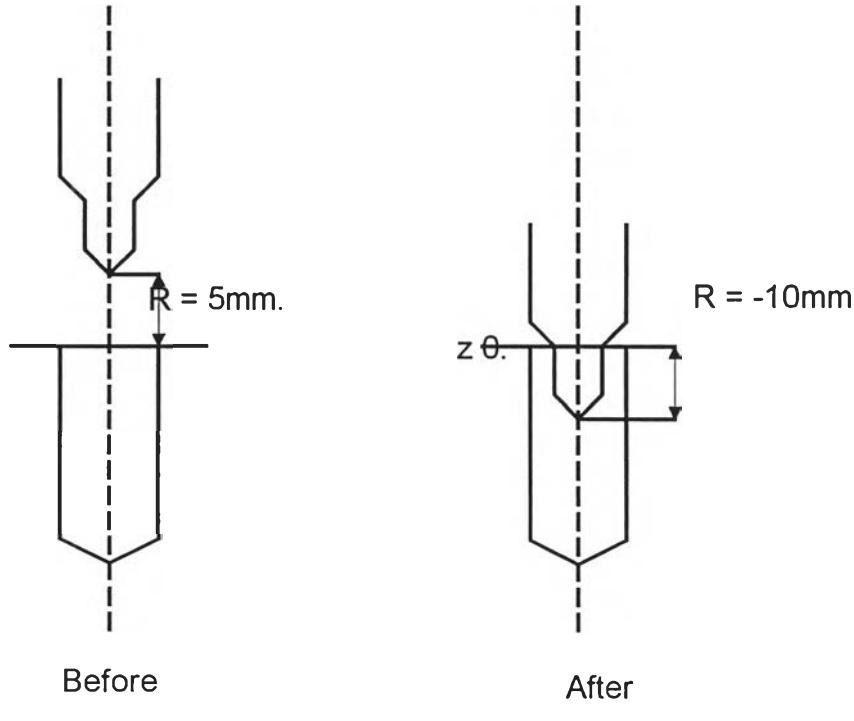
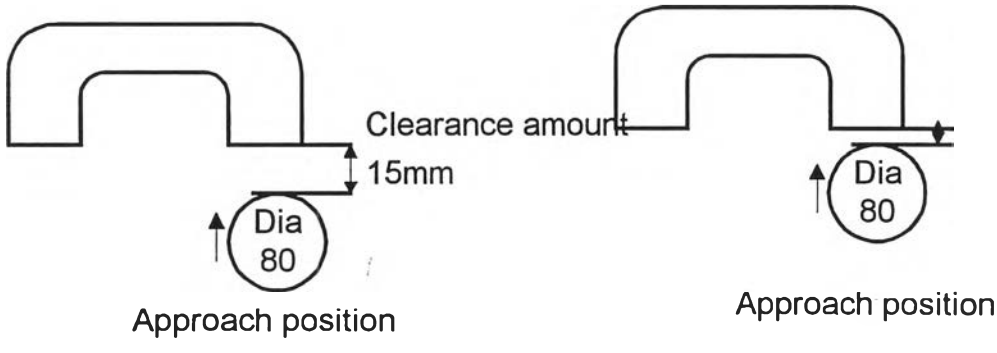


Figure 4.4 improvement of air cut time reduction for burnishing reamer

This tool will enlarge a diameter 14.3 millimeters to 15millimeters. Before improvement ; the tool tip was set at 5 millimeters from cutting surface. From the observation diameter of tool tip is smaller than diameter of raw material. The cutting point of tool is at second step of tool. R point can be

reduced from 5 millimeters to –10 millimeters. Because the cutting point of tool still far from cutting surface at the safety point.

2. Face milling. Figures 4.5 shows the approach point of face milling before cutting. The distance of face milling and work is 15 millimeters. Approach position can be reduced because it no affect with the quality of product.



Before After

Figure 4.5 improvement of cutting length reduction for face milling

- Result after reduce non-cutting time

  After reduced air- cut time machine time was reduced 18 seconds. Cycle time was reduced from 4.55 minutes to 4.25 minutes. Average time per shift is 450 minutes. Capacity was increased from 84 PCs/ shift to 90 PCs/ shift as a calculation in table 4.5.

Table 4.5 result after reduce non-cutting time

Before		After		
T(max)	Capacity (PCs/shift) at 85%	T(max)	Capacity (PCs/shift) at 85%	% improvement
4.55	$\frac{450x0.85}{4.55} = 84$	4.25	$\frac{450x0.85}{4.25} = 90$	$\frac{(90-84)}{84} = 7.14\%$

2. Reduction of cutting time.

Collect current cutting speed and feed rate for each tool, as shown in table 4.6. Tool which take long cutting time are tool No. 1,2 and 5. Tool which take long cutting time and not effect to quality of product will be considered first. In this process tool No.1 will be selected to improved because it is rough cutting.

Table 4.6 cutting condition for each tool

Tool No.	Tool	Time (sec)	Cutting condition		Recommended Cutting condition		Improvement plan
			Cutting speed(mm /min)	Feed (mm/rev)	Cutting speed(mm/ min)	Feed (mm/rev)	
1	Burnishing reamer	58.43	47	0.06	40-60	0.05-0.1	Increase feed.
2	Burnishing reamer	58.43	47	0.06	40-60	0.05-0.1	o
3	Spot facing	15.09	125	0.9			o
4	Tap M18	16.21	25	1.5	10-15	1.5	O
5	Face milling	52.57	628	0.16	500-800	0.05-0.3	O
6.	Tap M6	15.28	22	1.0	10-15	1.0	O
7	Tap M8	37.33	18	1.25	10-15	1.25	O

1. Change rough cutting tool.

Objective of rough cutting is to reduce depth of cut for finished cutting. Good surface roughness do not need for this process. Cutting condition for these tools were shown in table 4.7. It can be found that cutting speed and feed rate of carbide drill is higher than burnishing reamer. The using of carbide drill instead of old burnishing reamer, cutting time was reduced from 58.43 to 19.23 seconds.

Table 4.7 compares cutting condition between reamer and carbide drill.

	V(mm/min)	F (mm/rev)	N (rpm)	F mm/s	Used time
CARBIDE DRILL	50	03	1500	300	19.92
OLD REAMER	40-60	0.05-0.1	1000	60	58.43

(Resource : Toshiba Tungaloy Catalogue, 1994)

Machine time of process 8 was reduced from 4.22 minutes to 3.58 minutes. Total working time of process 8 is machine time + manual time or 3.58 + 0.25 = 3.83 minutes. Refer to table 4.3,

the second longest operation time is process No.2,3 which take 3.93 minutes. Standard time for this line was transform to 3.93 minutes. New bottleneck is process No.2. Figure 4.6 shows time charts after improve process 9. Figure 4.6 compare between machine time before and after improvement. First column is time before improvement and second column is time after improvement. Capacity per shift was increased from 84 pieces / shift to 97 pieces / shift as shown in table 4.8.

Table 4.8 result after reduce cutting time and non-cutting time

Before		After		
T(max)	Capacity (PCs/shift) at 85%	T(max)	Capacity (PCs/shift) at 85%	% improvement
4.55	$\frac{450 \times 0.85}{4.55} = 84$	3.93	$\frac{450 \times 0.85}{3.93} = 97$	$\frac{(97-84)}{84} = 13.6\%$

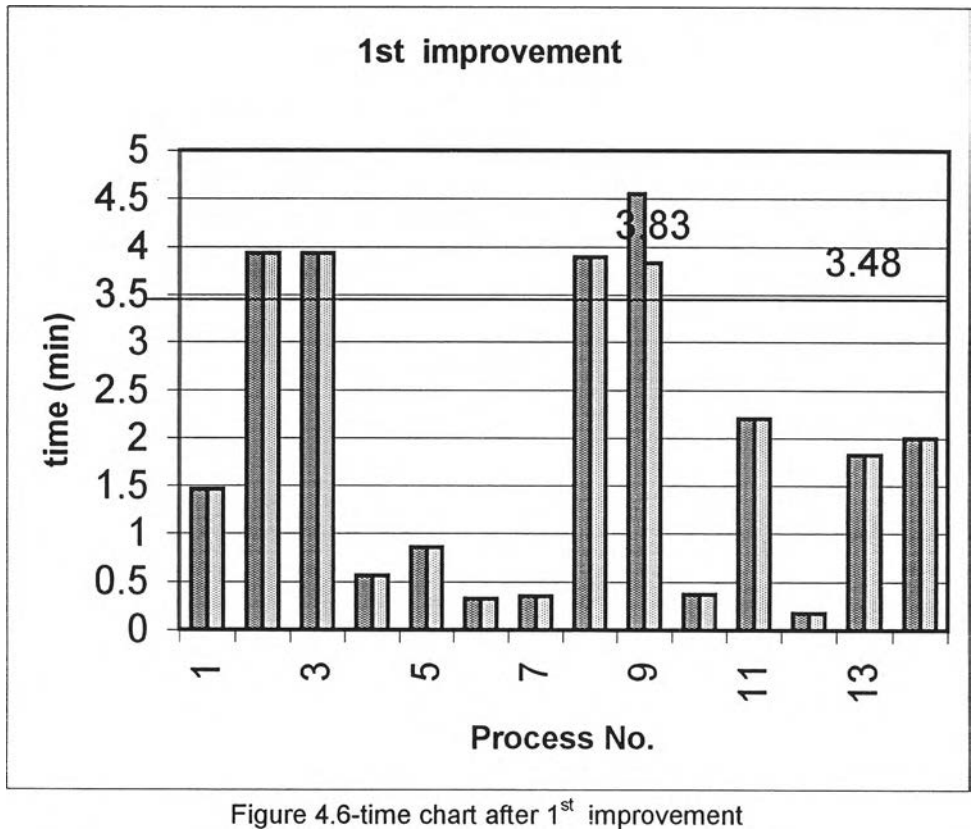


Figure 4.6-time chart after 1st improvement

4.6 Improvement item for process 2&3

The next bottleneck machine is machine No.2 and 3, which operate the same process. It was improved

1. Non-cutting time
   By reduce air-cutting time of reamer diameter 6, 16.5,11. The improvement process are as same as process No.9. After improvement time was reduced 8.4 seconds
2. Cutting time improvement.
   By change high efficiency tool. Boring cutter will be changed insert from carbide to diamond insert which harder than former. The standard cutting speed can be increase. The time of cutting can be reduced 6.4 seconds.

Table 4.9 result after reduce cutting time and non-cutting time of M0502

Before		After		
T(max)	Capacity (PCs/shift) at 85%	T(max)	Capacity (PCs/shift) at 85%	% improvement
3.93	$\frac{450 \times 0.85}{3.93} = 97$	3.83	$\frac{450 \times 0.85}{3.83} = 99$	6.18%

Machining time for process 2 & 3 was reduced from 3.93 to 3.7 minutes. Figure 4.7 shows time chart after reduces cutting time and non- cutting time. The bottleneck is machine No. 9 which take 3.83 minutes. Capacity of line was increased from 97 pieces/shift to 99 pieces/shift or 6.18%, as shown in table 4.9.

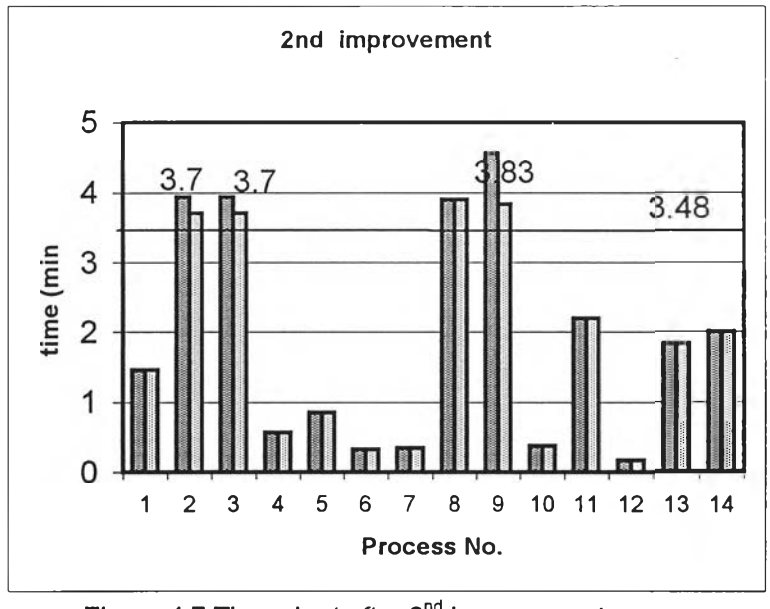


Figure 4.7 Time chart after 2nd improvement.

4.7 Conclusion

Total improvement of operation time is 16 %. Standard time was reduced from 4.55 minutes to 3.83 minutes in process No. 2, 3 and 9. Figure 4.8 compares time chart for each process the first column is time before improvement the second chart is time after improvement.

The other approach to increase efficiency is reduction of down time losses. The next chapter will analyze and countermeasure down time losses of lines M05.

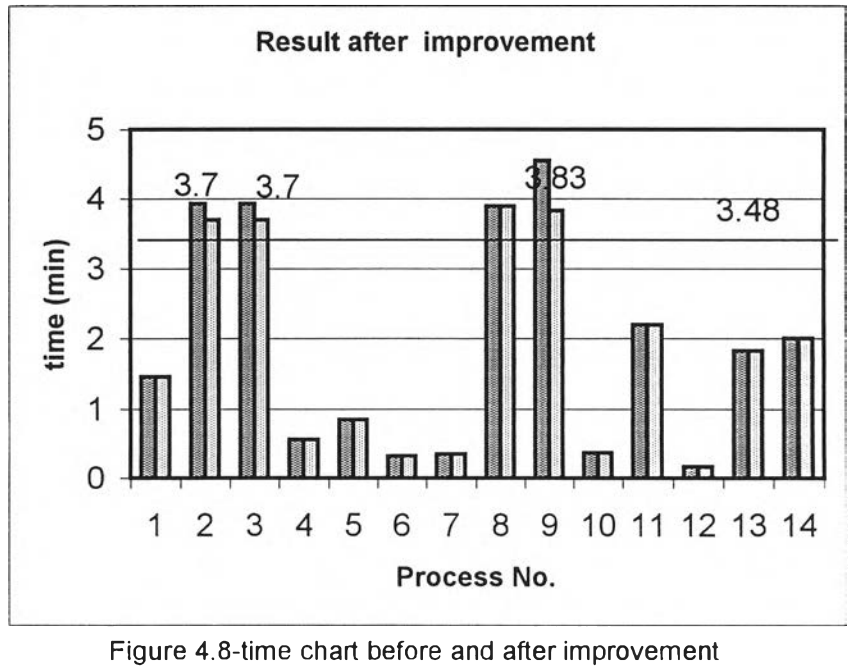


Figure 4.8-time chart before and after improvement