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Operator Idle Time Rectification as the Solution to Cycle Time Reduction in Oxygen Sensor Production

Melvin Harsono[a], Joni Welman Simatupang[b]

Department of Electrical Engineering, Faculty of Engineering, President University, Bekasi, Indonesia
[a]melvin_harsono@yahoo.com, [b]joniwsmtp@president.ac.id

Abstract. In factory works, there are systems that need to be followed in order to create a well-ordered process such that Just In Time (JIT) production can be reached. The lean manufacturing principle is one of the solutions for sustainable factory system. Within the lean manufacturing system, there are many tools that can be applied for sustainability and improvement. In this paper, Kaizen, the Japanese business philosophy as one of the lean manufacturing principle tools, is applied to give an improvement in reducing production cost. It is done by continuous observation, note, and analysis of time consumption required by the production line. A new Kaizen analysis from a new point of view is applied by comparing the impact of adding operator to the production line to the Over Time (OT) cost and renewing part of the machine-tool mapping for faster Takt Time (TT). Kaizen activity was successfully analyzed. It shows that the production Cycle Time (CT) can be deducted by 0.5 seconds which will reduce the production revenue cost by 10.8%.

Keywords: Lean Manufacturing, Kaizen, Just In Time, Cycle Time, Continuous Improvement.

1. Introduction

In production system of a company, there must be cycle time that counts a product time of each product and its type that is usually made in the domain of seconds. The function of cycle time is to see the number of products that can be delivered in a very short period, whereas the production itself is considered as mass production that involves machines and man-power.

Production department of a mass production company should have a certain concern on its production management. While in the production management, maintaining balance production line condition as its standard is a compulsory task for the production department, because the properly balanced production line cycle time will be easier to improve [1]. Besides, cycle time, the micro scale of production timing management, is considered to be the standard to control the number of products that must be produced in order to satisfy consumers order.

On the other hand, the production trend amplitude will not be stable in terms of time. As time goes on, order from customers will always have fluctuations depending on market condition that requires the product and the number of rivals that produce the same kind of product [2]. Therefore, there are many factors that can be the reasons of why cycle time should always be altered for satisfying demands of the company's customer.

As for X Corporation in Indonesia, a leading supplier of advanced automotive technology, systems, and components for major automakers, each production department has its own fluctuation of production trend. The case example in this paper is the oxygen sensor production. The oxygen sensor department of X Corporation is predicted to have a major rise in its prediction course production gradient. A notable example is that, in October 2015, the trend of line #2 of Oxygen Sensor 2WV type was about 146,000 pieces per month; however, in June 2016 the number had changed drastically to about 220,000 pieces. The increased number of demand from customer to produce more of the product will surely affect the micro scale of time calculation indeed. Therefore, the improvement in cycle time and maintaining the production satisfaction for consumer are the goal of cycle time management [3].

There are many methods to reduce the cycle time production. Some of them are parallel activity performance, timing improvement, interruption reduction, and activity sequence change. The focus of this paper is more towards the cycle time reduction technique by applying lean manufacturing principle for timing improvement. The expected results of the improvement in this paper are the reduction of the cycle time production so that the production cost can be pressed and the deduction of Over Time (OT) for operators.

2. Literature Review and Method

There are many principles that can be applied to improve the productivity level. In this paper, particularly, the lean manufacturing principle is considered for cycle time reduction. The lean manufacturing is applied to focus on the elimination of none-value added activities which will be a waste in the manufacturing process [4]. The waste, in this case, normally refers to the activity in which the cost will be higher due to the activity(s) that customer does not want to pay for. The production waste can be categorized into seven parts, which are: unnecessary waiting, unnecessary transportation, excess inventory, overproduction, defects, unnecessary movement, and over processing [5]. The item production flow is essential in generating less waste time. Customer, plan, and order cycle play important role for waste management, as given in Figure 1. Having the order from customer, a company can plan the number of items to be produced in the factory that later will be delivered to customer. The waste itself mostly happens between order-plan and plan-customer parts.

In Japanese manufacturing company, the waste-無駄 (*Muda*) in the production cycle basically refers to any kind of waste in the production system. The reduction of 無駄 (*Muda*) by several deep applications is done to reach the Just In Time (JIT) manufacturing [6]. JIT is defined as a way to produce the product as what, how long the time, and the quantity which are required. And the basic principle of JIT manufacturing is to produce the number of products corresponding to *Takt Time* (the maximum amount of time that is required to produce the number of products that will satisfy the customer demand).

Takt time can be represented in the following equation:

$$TT = \frac{ET}{N} \quad (1)$$

where *ET* stands for the provided effective time in a normal working day, and *N* is the number of production units on the day [7].

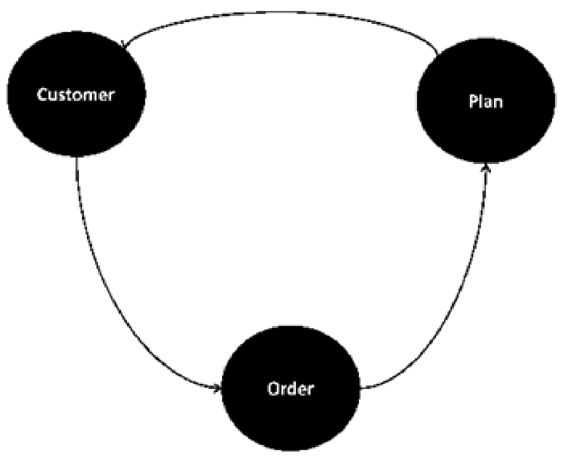

Figure 1. Production flow diagram

As the implementation of lean manufacturing to reach takt time for good productivity without excessive 無駄 (*Muda*), 改善 (*Kaizen*), a tool in lean manufacturing principle is applied. 改善 (*Kaizen*) itself means the change to make better condition which should be done continuously. The purposes of 改善 (*Kaizen*) are:

- As the visualization tool to control the improvement whether or not it is based on plan.
- As the improvement(s) document which has ever been done.

改善 (*Kaizen*) itself must be done continuously regardless of how much the impact can be to the productivity level. It should always be noted and analyzed well.

In relation to Cycle Time (*CT*) reduction study, the 改善 (*Kaizen*) can be applied by continuously observing the operator time consumption per process. The 現場 (*Genba*) or direct field observation can be conducted by measuring the production time consumption per machine and per process using stop watch. After that, data is analyzed continuously until it is decided whether or not machine improvement, man-power change, and/or machine mapping should be changed.

3. Result and Analysis

As the trend keeps growing in the oxygen sensor production, reduction of Over Time (OT) payment can be one of the alternative solutions in output reduction. The Over Time (OT) payment might be deducted if the production runs faster than the momentarily condition, this means that the cycle time in the scale of seconds must be deducted. At the same time, the feasible cycle time reduction that can be done to give a relatively big impact is by reducing the line production cycle time; for example, from 7 seconds to 6.5 seconds.

The following is the calculation of *Takt Time*:
It is known that:

- Order / Month = 220,806 pcs
- Order / Day = 10,771 pcs (20.5 Working Day)

Therefore, the Takt Time (*TT*) is

$$TT = \frac{ET}{N} \times 3600'' \times LOR$$
$$= \frac{16 \times 20.5}{220806} \times 3600'' \times 87\% = 4.65''$$

where *LOR* is Line Operation Ratio, and the purpose of multiplication by 3600″ is to change the scale into seconds. It is also known that the working *CT* of Line #2 production of X Company is 7″. Thus, in this case *CT* > *TT*, which means that Over Time (OT) is required.

Oxygen sensor production department of X Corporation has two groups of production system, the morning shift and the evening shift. Therefore, calculation of OT per group should also be attached. If the OT of normally limited hour is added (2.5 H addition) to each group, then the number of oxygen sensors produced is calculated as follows:

Capacity Oxygen Sensor Line #2 in NWD (Normal Working Day):

$$C = \frac{WH}{CT} \times 3600'' \times LOR \quad (2)$$

where *WH* is the Working Hour, *CT* is the Cycle Time, *LOR* is the Line Operation Ratio, and the purpose of multiplication by 3600″ is to change the scale into seconds.

$$C = \frac{16 \times 20.5}{7''} \times 3600'' \times 87\%$$
$$= 146757 \text{ pieces in NWD}$$

NWD + OT 2.5 hr/day/group

$$= 146757 + \left(\frac{2.5 \times 20.5}{7''} \times 3600'' \times 87\%\right) \times 2 \text{ groups}$$

$$= 146757 + 45861 = 192618 \text{ pieces}$$

192,618 pieces out of 220,806 pieces means that only 87% of the targeted production is achieved even though OT has already been applied. The additional production is later done on holidays or Saturdays, out of the 20.5 Normal Working Days.

Observation and calculation are done, and finally, the problem and its solution to deduct the cycle time from 7″ to 6.5″ are found. In the process, the most problematic condition, such that the production of oxygen sensor may be postponed, is located in the region of body assembly of oxygen sensor. Difference of body assembly and wire assembly of oxygen sensor production cycle time and problem of not reaching 6.5″ target are shown in Figure 2.

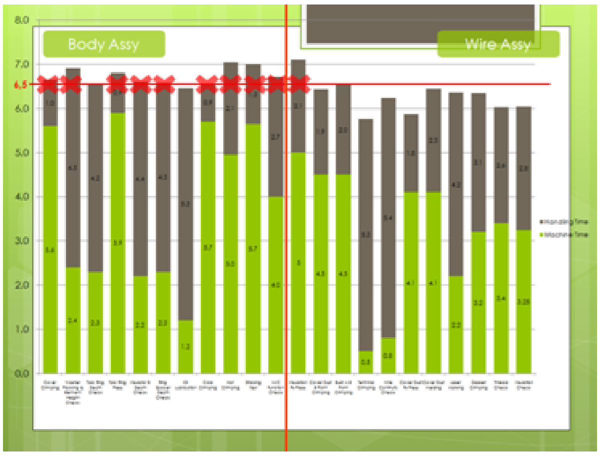

Figure 2. System architecture

From the diagram in Figure 2, there are 10 processes that have not reached the target of 6.5 seconds and thus may delay the production process. Nine out of the 10 processes are the processes in body assembly process, which means that more improvement should be done on the body assembly processes. Normally, the improvement that can be given is the machine improvement for faster production. The machine improvement is surely a better improvement for larger quantity and faster production. However, large amount of investment is required. The investment itself takes the time domain of years to cover its lost. Within the condition that rivals or other companies that keep on giving discounts and special prices to the customer, the corporation must also think of another innovation to satisfy customers need.

Table 1. Suggestions, relative cost, and the impact

No.	Type of Suggestion	Cost	Level of Feasibility	Time required to implement/trial
1	Machine modification	Very high	Low	10 months
2	Over time addition	High	High	1 week

Some suggestions might be delivered for the matter of cycle time reductions in production line as summarized in Table 1.

The idea, consideration, and comparison of the innovation which must be implemented on the body assembly process improvement, then it is decided that the improvement that must be done is actually on maximizing the operator cycle time consumption. In reality, it is unethical to force operators to work more than their limit such that the cycle time is short. For that reason, the improvement that can be done is degraded into only 0.5 seconds of reduction.

From Figure 2, it can be known that the body assembly processes need certain attention for the deduction of cycle time. In this experiment, the improvement that is given is totally different in terms of point of view. Generally, the suggestion that may be given to the factory to reduce its outcome is by reducing the number of man-powers being used inside the production processes. However, for this experiment, the suggestion for cycle time reduction is made to be in the different form. It is suggested that the number of operators must be added instead of being deducted. Calculations are done to prove that corporation will have benefit rather than lost. The following is the calculations of comparison that have been made simple to be read:

Current Condition & OT (if 7.0 seconds *CT* is applied):
220806 − 146757 = 74049 additional pieces.

Required hours to produce 74,049 in a month:
(74049/146757) × 16 = 8.1 H/day (5 days a week)
⇒ 8.1 − 5.5[*1] = 2.6
⇒ 2.6 × 4 (days of over time) + 8.1 (Friday[*2])
⇒ 18.5 hr on Saturday

[*1] Where the 5.5 is 3 hr on the day shift & 2.5 hr on the evening shift
[*2] Specially on Friday, there is no OT applied

The cost/hr of OT:
Day shift: 3 × 25,000 = 75,000 × 16 = 1,200,000
Evening shift: 2.5 × 25,000 = 62,500 × 16 = 1,000,000
Total = 2,200,000 per day
Normally (4 days of OT a week) = 8,800,000 a week

Certain OT cost on Saturday:
18.5 ⇒ 9.25 × 25,000 = 231,250 × 16 = 3,700,000 (day shift)
⇒ 9.25 × 25,000 = 231,250 × 16 = 3,700,000 (evening shift)
Total = 7,400,000 per Saturday

A month calculation: (8,800,000 × 4) + (7,400,000 × 4)
= **IDR 64,800,000**

On the other hand, if one operator is added on the body assembly processes in each shift for the improvement based on the 改善 (*Kaizen*) activity, the result comes out to be very interesting that the cost would be lower.

If 6.5 *CT* is applied; OT will be:
220806 − 158046 = 62760 additional pieces.

Required hours to produce 62,760 in a month:
(62760/146757) × 16 = 6.8 H/day (5 days a week)
⇒ 6.8 − 5.5[*1] = 1.3
⇒ 1.3 × 4 (days of over time) + 6.8 (Friday[*2])
⇒ 12 hr on Saturday
[*1] Where the 5.5 is 3 hr on the day shift & 2.5 hr in the evening shift
[*2] Specially on Friday, there is no OT applied

The cost/hr of OT:
Day shift: 3 × 25,000 = 75,000 × 17 = 1,275,000
Evening shift: 2.5 × 25,000 = 62,500 × 17 = 1,062,500
Total = 2,337,500 per day
Normally (4 days of OT a week) = 9,350,000 a week

Certain OT cost on Saturday:
12 ⇒ 6 × 25,000 = 150,000 × 17 = 2,550,000 (day shift)
⇒ 6 × 25,000 = 150,000 × 17 = 2,550,000 (evening shift)
Total = 5,100,000 per Saturday

A month calculation: (9,350,000 × 4) + (5,100,000 × 4)
= **IDR 57,800,000**

Thus, if it is compared between the previous condition (before applying improvement – no additional operator) and the condition after improvement (with two additional operators), there can be actually benefit with the amount of 64,800,000 − 57,800,000 = IDR 7,000,000 per month. Within a year, the benefit would be 12 × 7,000,000 = **IDR 84,000,000**. This big amount of benefit, if it is applied, can be used to search for another possibility of improvement or event innovations in marketing and selling the product for customer.

Calculation and new point of view to position new employees in this case are not enough. There is still one more process in wire assembly of X Corporation that still needs special attention for improvement consecutively together with the additional operators. The problem that is found in the process of wire assembly that needs special attention (i.e., insulation fix press) is actually because of time consumption before having the materials being inserted into the machine. For the case of insulator fix press, the operator should prepare 6 different materials including the lead, insulator, and some other materials of oxygen sensor; which are then being put inside the machine for the process of pressing. In the diagram of Figure 2, the total time that is required for the machine to process is very long, i.e., it requires 5 seconds for the machine to press and give the result to operator. The handling time that the process consumes in this case is 2.1 seconds on average. From its feasibility, there can be deduction for handling time by maximizing idle time of operator prior to the insulation fix press process, i.e., the machine function check process.

The machine function check has 2.7 seconds of handling time and 4.0 seconds of machine time on average. To say the truth, after truly doing the observation, the operator of this process has idle time much that is not used to check the condition of product after machine process. While waiting for the machine to process in 4 seconds, the operator will take in maximum 2 seconds to check the condition of product after machine process, and spend the rest of it doing nothing just to wait for the machine to end its process. This is the point that can be taken into use of role changing of cycle time management. When it is applied, based on the trial / experiment, the process of insulator fix press that exceeds much from the targeted can be deducted to 1.2 seconds of handling time on average. The role switch improvement has successfully decreased the time consumption and made the cycle time of insulation fix press process to 6.2 seconds.

For the implementation to reduce the cycle time through the observation of operator cycle time and idle time, benefit calculation is done and may give X Corporation greater sale improvement opportunity as given in Figure 3.

Item		Before	After	Evaluation
Line Cycle Time		7 seconds	6.5 seconds	↓ 0.5 seconds
Capacity / Month (NWD)		146757 pcs	158046 pcs	↑ 11289 pcs
Capacity / Month (With O.T.)		192598 pcs	246927 pcs	↑ 54329 pcs
Capacity / Day		7159 pcs	7710 pcs	↑ 551 pcs
Capacity / Day (With O.T.)		9395 pcs	12045 pcs	↑ 2650 pcs
Qty / Hour		447 pcs	574 pcs	↑ 127 pcs
Over Time / Month / Group	Day	85	72	↓ 13 hr
	Evening	77	64	↓ 13 hr
Cost Over Time / Month (40p)		**Rp64.800.000**	**Rp57.800.000**	↓ **Rp7.000.000**
Saving cost per year -> Rp84.000.000				

Figure 3. Difference before and after improvement implementation

4. Conclusion

The experiment was done by looking from different point of view for improvement and 改善 (*Kaizen*) application routinely. In general, the improvement will have fewer operators to decrease the amount of budget in one department such that the budget may be allocated for another improvement / sales innovation. However, in this paper, a new point of view is applied where actually it is practically easy to be applied, feasible, low cost, and reliable improvement to have additional operator in order to reach the production goal (JIT). Indeed, the calculation was also applied and successfully showed that by having a new operator, the X Corporation could save IDR 7,000,000 which is 10.8% of the monthly OT operator cost.

Consecutively, the improvement of cycle time reduction was done by seeing the idle time of operator prior to the process that was wished to be improved. Making use of the idle time while waiting for the machine process to be done and then assisting the following operator for the next process (role switching) is a new improvement in industrial management.

All in all, *CT* reduction as the result of continuous improvement 改善 (*Kaizen*) on *CT* observation brings a new solution that is to add operator number but it brings more profit to the production line instead.

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