The Improvement of the Airbag Manufacturing: A Case Study of the Automotive Safety Equipment

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***Abstract*- The main objective of this research is to improve the efficiency of the airbag manufacturing. The side airbag production line has been selected as the pilot study. The production line efficiency improvement is necessary to respond and support the customers' demands as well as increasing the productivity of the company.**

The side airbag production line under studied was not being able to fulfill the increasing customer demands. The research started by collecting the data represented the existing situation. The data are then analyzed and the Industrial Engineering techniques are applied. The ECRS and Yamazumi Chart technique for line balancing are applied to improve the process. In order to reduce the defective in the process, the Kaizen technique was finally implemented.

It has been proven that the techniques employed in this study can improve the efficiency of the side airbag manufacturing. The results obtained were: three operators have been reduced, the output is increased to 84 pieces per shift, and the productivity is increased from 3.16 pieces per man-hour to 4.43 pieces per man-hour. The product quality also improved. The defective rate is reduced by 1.99%, from 3.07% to 1.08%. The implementation of the line balancing technique reduces waiting time, so thus the OEE is increased by 9.22%, from 87.72% to 96.94%.

***Keywords*- Line improvement, Line balancing, Kaizen, Overall Equipment Effectiveness (OEE)**

I. INTRODUCTION

Automotive industry plays an important role for the country development [1]. It has impact on economic growth, labor hiring, value added, automotive development and support to other industries. Thailand has the policy to promote and continuous development of the automotive industry since 1961.

The automotive safety equipments are one of the major components for the automobile. Due to the high growth of the automotive industry in Thailand for the past decades, it is necessary to improve the productivity and quality of products. The side airbag manufacturing of the studied plant also faced the problems of productivity and quality improvement. For example in the stitching process, there were 16 steps with 19 workers causing high idle time in the production line. The output rate was lower than the sale volumes required by the marketing department. The defective rate was high due to the rush production. The over equipment effectiveness (OEE) was also low due to high idle time and high defective rate. Thus it was necessary to improve this side airbag production line.

II. OBJECTIVES

The main objectives of this research are as follows:

1) To improve the efficiency of the side airbag manufacturing process.

2) To reduce the defective rate of the side airbag manufacturing process.

III. LITERATURES REVIEW

A. The Productivity

Productivity is an average measure of the efficiency of production. It can be expressed as the ratio of output to inputs used in the production process, i.e. output per unit of input.

$$Productivity = Output / Input \qquad (1)$$

There are types of productivity [2]:

1. Partial Productivity is a ratio of output to each resource such as labor productivity, capital productivity, material productivity, and energy productivity.
2. Total Factor Productivity is a ratio of output to net capital and labor which net output minus the cost of materials and services.
3. Total Productivity is the ratio of output to all resources use.

The rate of increase in productivity indicates the improvement in efficiency and performance [3]. It provides a means of increasing productivity by reducing production costs. (Reduction of resource use) that is the way to increase the yield maximum results increasing productivity by reducing capacity or increasing productivity by reducing costs.

Productivity increase can be achieved in several ways.

1. Output increase, inputs unchanged.
2. Output increase, inputs decrease.
3. Output unchanged, inputs decrease.
4. Output increase high ratio more than inputs increase.
5. Output decrease low ratio less than inputs decrease.

B. Line Balancing [4]

Process is an assembly of small components. The finished product is characterized by an assembly line. The assembly line represents the workflow components that are running continuously. Each assembly line may be different in terms of the layout of the machine tool assembly line, the ability of workers and jobs on the assembly line. Thus, the time it takes to perform is different. When each sub-process is the time to work (Cycle Time) unequal to make production lines that caused unemployment in certain stages it may have wide-ranging and serious to the bottleneck in the process which caused emptiness to operate machines with less efficiency. In order to reduce these problems, they have devised improved. The solution to this matter is balance of production; an allocation of the working time (Cycle Time) in each step or process that is most similar to cater the priorities in the work-out. The allocation for each work station to ensure consistency is proportional from elimination process without the need for reducing the duration or distance of moving.

To balance production line, what is crucial in the process of production? We need to know sequence of work at each stage of work requirements or production volume. This will allow us to analyze and improve processes and to determine the balance of the production line is the time spent in each stage of the work process and to have effective results when information is accurate and reliable. The steps to balance the production line is scheduled to begin around the time of production, relationship of the order process or smaller tasks together To the individual work stations. The difference of time spent on each work station is minimal. If the event cannot fit to the number of set up stations, it can be solved by increasing the number of work stations as appropriate to the individual work stations. The information put to use in the analysis can be put in chart balance workloads (Yamazumi chart).

Balancing the production line to measure or evaluate the effectiveness and efficiency of the production line has been improved; it is regarded as extremely important. To compare results before and after balancing the production line with the following formula.

$$\% \text{ Line Efficiency} = \frac{\text{Total time}}{\text{Number work station} \times \text{Max Cycle time}} \times 100$$

C. ECRS [5]

ECRS is the general principles of how to improve the work study to streamline workflow to increase productivity as follows.

1. *Eliminate* is the removal of some unnecessary parts or useless away. This is because the job would mean an unnecessary waste of time, labor, materials or money, the costs to operate or invest in it. Step to consider in order to eliminate starts from "Is that work able to eliminate?" as follows.

- This step may not be important anymore.
- This may be a step up for the convenience of staff only.
- This step can be eliminated if the new sequence.
- This step can be eliminated if the better tool.

2. *Combine*, The process includes multiple parts together to same step. When unnecessary work cut out but remains work needed or cannot cut out. The next step is found out the task or the job that needed to be integrated into the new by consider "able combine?" as follows.

- Workplace or tools new design.
- Change work sequence.
- Materials or details part change.
- Skill up.

3. *Rearrange*, when eliminate and combine doesn't work will be improvement by location change, operator change or rearrange by consider "able rearrange?" as follows.

- Reduce work sequence to short or simple.
- Reduce transportation or motion.
- Saving work area and time.
- Increase efficiency tool.

4. *Simplify*, improve work to simple to do and high performance such as complex work and difficult to understand find to do as simple by consider "How to improve?" as follows.

- Re layout.
- New tooling.
- Training, closes control and service.
- Break the task down to the sub.

First to be done is eliminate because some task was combined rearranged or improved but later we witness it's unnecessary. Second to do is combine and rearrange. The last to improvement or make it simple to do task compact and right.

D. Kaizen [6]

改 (Kai) Japanese means to change or correction and 善 (Zen) means to aim to perfection 改善 (Kaizen) means to change to perfection. Kaizen has profound implications that require additional media revolution and that the practice occurred, it must be done continually, with no end date. Kaizen management style, although not the main task of the management. But at the same time it's not the employees unilaterally and Kaizen is not just a formula adjustment procedure in the company. But what is it about this concept; the administration must be built into the minds of all employees and executives. To change the way they live in accordance with the practices. The results of this strategy can be enormous, so it can actually happen.

In a big picture, strategic management, Kaizen is a way of management that delivers the confidence of the staff, everyone in the organization should maintain and develop the capacity of its own production system for better consistent with a "systemic practice "by not mind it "Regulation" is that perfection is not changing any more.

In staffing levels practicing of Kaizen is comparable to a priest said prayers or ecclesiastical ministry is done repeatedly each day by just not practical to complete or to kill time. But to be mindful of the questions focused on identifying, analyzing and searching for answers on the subject of the question. Then the next day I did the same to put forward a more enlightened approach day.

By these concepts when taken together with steps as a way of correct implementation, the power to solve problems with Kaizen management strategy can be applied to deal with the systemic problems that have extensive, concrete and very versatile. From a quality control Reduction process Inventory Management Transportation management, etc. The solution is being tested by those in direct environment. It is a collection of recipes or instructions for further handling. The response from the experimental stages, it is often not practical approach which is enough to collect only the best content. It will be innovative, as Toyota was finally able to create manufacturing standards TPS (Toyota Production System), which uses the Just-in-Time (JIT) to control the production car "made specific needs to do so only and a number like "more complete. It is the result of studies and experiments through the Kaizen in a subset of the system continuously. 5 elements to be done in Kaizen

1. Teamwork
2. Personal discipline
3. Improved morale
4. Quality circles
5. Suggestions for improvement

These elements need to be prepared seriously before initiating the operation. If you lack strong foundation potential problems which hinder the Kaizen is likely to be very high. Examples of these issues include.

• The transfer some work to do Kaizen supervisor could understand that they were considered potential decline. Cause opposition and refused to leave the job.

• Noncompliance of those who do not believe that the trial process will produce better results. Or there is a possibility.

• Disappointed in the result, no progress could be undermined morally.

• The system is not sustainable because of the lack of assurances by the administration to take a serious Kaizen.

• The lack of adequate support tools.

The Kaizen goal is to reduce waste or muda (無 駄) thus the "Elimination of Waste" is the first step to start making Kaizen.

The aim of this step is to look for and what to get rid of clutter or slow-moving organizations to pay attention to things that are not helpful in any way to make the most in of things to get rid of it. "The process or step that cause waste in" descending order of severity as follows.

1. Defective products
2. Over-production
3. Transportation
4. Waiting
5. Excess inventory
6. Motion
7. Extra processing

For example, we may look in the garden. Experimental drip system to replace the water that we need to do is to gradually and regularly collect water that drips per minute, the speed of growth, or the fruits of the trees. The concept is simple nearby on the Elimination of Waste to reduce unnecessary water. (Over-production) and to stop the movement was spared (Motion) on the need to water the tree itself. These start from the statistics about the various functions. Then, test preparation to reduce the problems, which includes the target preferences to record and modify experiments. And the preparation and trial practice on the Elimination of Waste and aims to reduce the problem in any part of it. Then next step is taking action.

E. JUSE's QC Story [7]

The solution of the Confederation of Scientists and Engineers of Japan (Japanese Union of Scientist and Engineer: JUSE) administration has proposed a QC Circle for a way to solve quality problems seven in steps.

1. Choosing a topic assigned missions themselves; are responsible for what. The quality indicator, then check the results of the current operations. To determine the quality problem, making a selection problem will be solved to determine the topics. The topics will be in the form of fixing what not desire to is over wish list.

2. Understanding the situation and goals. This step consists in choosing the product characteristics for control (control characteristics) that is used to judge the effectiveness of the solution. I understand the situation with the means. Find something that is not desirable in the present and the possibilities of such things in the past (Hosatani 1992: 82) by way of a major feature of the situation is using knowledge of the variations in the classification of information. In order to understand the situation then target the problem in the form of the amount that must be corrected within a specified period.

3. Event planning solutions the procedure is distinguished QC Story of Confederation JUSE is planning activities to address the issue of who did what, how, through the Gantt chart (Gantt chart) by the action must have come from understanding the status issue to be resolved in the second stage to determine the activities required to fix the problem. The resources used to schedule and assign responsibilities. The plan is an important tool in controlling the problem further.

4. Analysis of the problem at this stage, it has come from the collection of all possible causes of the problem. Then analyze the relationships between characteristics, quality-oriented education system. And why are interrelated by using the appropriate QC. He summed up the root causes of quality problems.

5. The counter measures and applies. After studying the root causes of the problem. The next step is to determine the appropriate counter measures. Start to define the concept of counter-measures such as eradicated twist the separation between normal and abnormal. Constant and variable, etc. (see the details of future episodes of Hosotani 1992: 96) and has already defined the concept to create an alternative for counter measures. And counter measures for further implementation.

6. Confirmation of results in this process, will consider the use of retaliatory measures in step 5 to consider the side effects. (Side-effect) may occur. Then consider either the result of the improved performance. To make a comparison with the target set in Step 2, and if the result is lower than the target. It is wise to consider the root causes of the problem and devising new measures. And if the result has been exactly the target please identify the benefits obtained from the update

7. Preparation of standard and custom control system. After the bundle runs counter measures to take and pass the results confirm that the results meet the set targets. It should continue to curtail the draft standard, so that all parties have a trial. Then make the appropriate changes to work processes. Then determine how to control which should be set up to control item and check points that will provide education or training in the new methods of accountability and kept it.

IV. RESEARCH STEPS

4.1 Process Study

This study was conducted at the manufacturing facility for automotive safety products, the side airbags model: A. The process steps include cutting, sewing and packaging. The longest process time is the sewing process. This study was focused on the sewing process in order to improve the efficiency of this line.

4.2. *Problems identification*

In 2014 the demands of the side airbag model A is 539 pieces/shift (pieces/7.7 hour) but the actual output were 448 pieces/shift. The line efficiency was 65.7 %, the defective rate was 3.11% which is higher than the target of 3.0%. The OEE target is 90%, but the actual OEE was 85.06%. The company's target for the year 2015 of OEE is 93% and for the defective rate is 1.5%.

4.3 Data collection

In the sewing process of the side airbag model A, there are 16 steps with 19 workers and the layout was a straight or I line as shown in Fig. 1. The bottle neck operation was at sewing station no. 4 and 8 as shown in Fig. 2. The line efficiency was 65.7%. In 2014, the output of side airbag model A was 223,450 pieces and defective was 6,950 pieces or 3.11%.

Sewing No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Worker	2	1	1	**2**	1	1	1	**2**	1	1	1	1	1	1	1	1

Fig. 1 The I line of the side airbag sewing process

Fig. 2 The Yamazumi Chart of the side airbag sewing process

4.4 Root cause analysis

The Pareto analysis identified the top three causes of defective which were thread fluffy, thread loose and no red tread which were accounted for 77.2% as shown in Fig. 3.

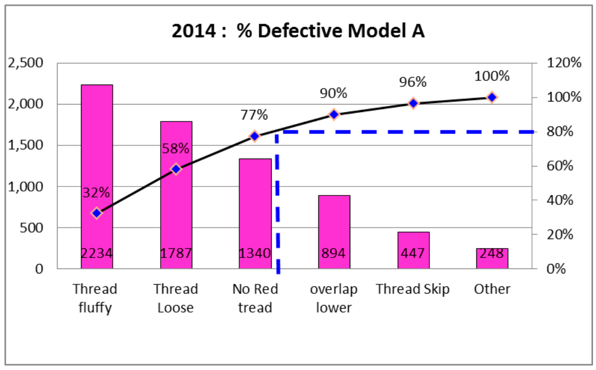

Fig. 3 Pareto chart of % Defective of Side Airbag Model A

4.5 Improvement

Once the problems and root causes had been identified, the improvement plan had been developed. To improve the line efficiency, the line balancing technique incorporated with the ECRS, the Man-Machine chart, and the Yamazumi chart were implemented. For defective reduction, the Kaizen technique and 7 QC Tools had been applied. The comparisons of production line performance, before vs. after improvement, using various indicators were then performed.

V. RESULT AND DISCUSSION

5.1 Improvement of sewing station no. 4 and 8

From the Man-Machine chart as shown in Fig. 4, it's found that the sewing station no. 4 and 8 containing 2 workers. There were non-value added activities that can then be removed using the improvement method as follow:

Improvement of sewing station no. 4

1. MAN1 and MAN2 were waiting and preparing for the next piece after the previous sewing piece was finished, causing an idle time of 18 seconds per worker, thus the total idle time for the two workers were 36 seconds. In addition, the MC1 were idle during workers' preparation for the next sewing piece by 12 seconds per worker, thus the total idle time for MC1 was 24 seconds.

2. MAN1 and MAN2 each spend 9 seconds for inspection of the finished piece, causing 18 seconds of idle time for MC1.

Before Improvement

MAN1and MAN2 each has 48 seconds of idle time and 57 seconds of working time accounted for 54% of working time.

MC1has 69 seconds of idle time and 36 seconds of working time, bring about 34% of working time.

After Improvement

One worker was eliminated. The operations steps have been modified. The modified Man-Machine chart is shown on Fig. 5. The cycle time is within the required output rate. There is no idle time for the worker. The total idle time of MC1 is accounted for 48 seconds for piece work preparation, loading and unloading of piece work.

Improvement results

For sewing station no.4:

- One worker was eliminated.
- Cycle time was reduced to 84 seconds.
- Worker percentage of working time was increased from 57% to 100%.

- MC1 has 48 seconds of idle time and 36 seconds of working time, bring about 43% of working time which is increased by 9%.
- The standard time was reduced by 13 seconds, from 111 seconds to 98 seconds.
- The output rate was increased by 9 pieces/hour, from 63 pieces/hour to 72 pieces/hour.

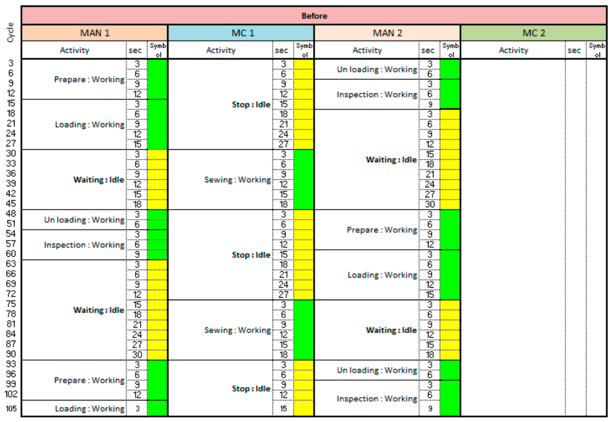

Fig. 4 Man-Machine chart of sewing station no. 4: before improvement

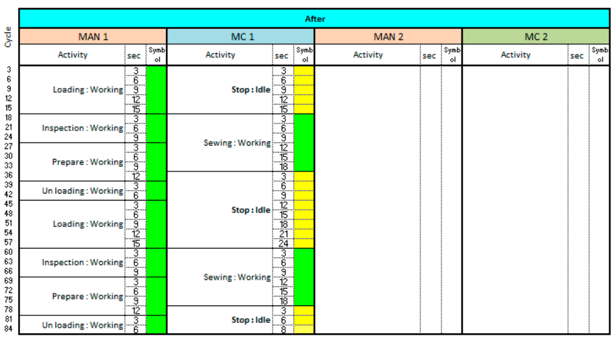

Fig. 5 Man-Machine chart of sewing station no. 4: after improvement

Improvement of sewing station no. 8

From the Man-Machine chart as shown in Fig. 6, it as found that:

1 MAN1 and MAN2 were waiting and preparing for the next piece after the previous sewing piece was finished, causing an idle time of 18 seconds per worker, thus the total idle time for the two workers were 36 seconds. In addition, the MC1 were idle during workers' preparation for the next sewing piece by 12 seconds per worker, thus the total idle time for MC1 was 24 seconds.

2. MAN1 and MAN2 each spend 9 seconds for inspection of the finished piece, causing 18 seconds of idle time for MC1.

Before Improvement

MAN1and MAN2 each has 48 seconds of idle time and 57 seconds of working time accounted for 54% of working time.

MC1has 69 seconds of idle time and 36 seconds of working time, bring about 34% of working time.

After Improvement

One worker was eliminated. The operations steps have been modified. The modified Man-Machine chart is shown on Fig. 7. The cycle time is within the required output rate. There is no idle time for the worker. The total idle time of MC1 is accounted for 48 seconds for piece work preparation, loading and unloading of piece work.

Improvement results

For sewing station no.4:

- One worker was eliminated.
- Cycle time was reduced to 84 seconds.
- Worker percentage of working time was increased from 57% to 100%.
- MC1 has 48 seconds of idle time and 36 seconds of working time, bring about 43% of working time which is increased by 9%.
- The standard time was reduced by 23 seconds, from 117 seconds to 94 seconds.
- The output rate was increased by 14 pieces/hour, from 60 pieces/hour to 74 pieces/hour.

The improvement was further performed by combining the operations in sewing station no. 6 and no. 12. Since the operations time in both stations were low, the worker of station 6 is now assigned to perform operations in station no 12 as well. The worker in station no. 12 was then eliminated. The number of workers assigned to each sewing station before and after improvement is shown on Fig. 8 and Fig. 9.

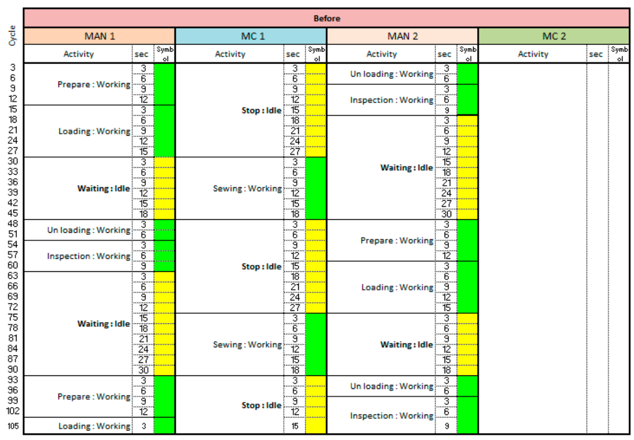

Fig. 6 Man-Machine chart of sewing station no. 8: before improvement

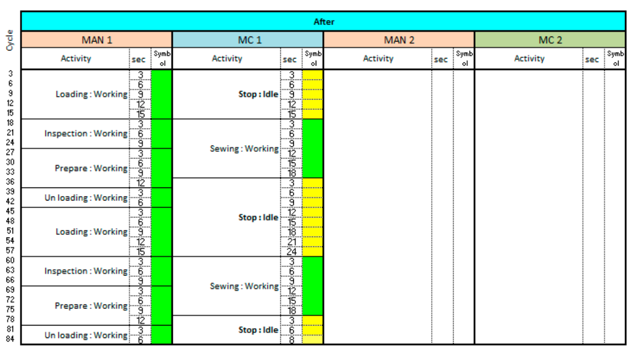

Fig. 7 Man-Machine chart of sewing station no. 8: after improvement

Sewing No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Worker	2	1	1	**2**	1	1	1	**2**	1	1	1	1	1	1	1	1

Fig. 8 Operators assigned to sewing station: before improvement

Sewing No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Worker	2	1	1	1	1	0.5	1	1	1	1	1	0.5	1	1	1	1

Fig. 9 Operators assigned to sewing station: after improvement

The operations time for all sewing stations after the improvement are shown in Fig. 10. From the Yamazumi chart, it is shown that the oprations time for all stations are within the required cycle time.

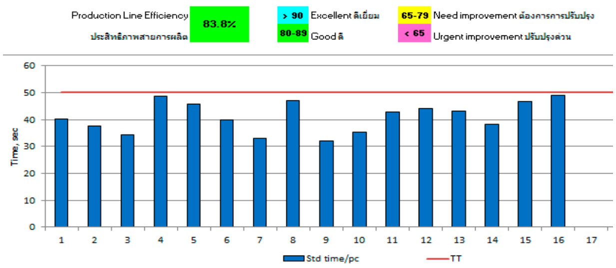

Fig. 10 Yamazumi Chart after improvement

Summary of the sewing station improvement:

- Three workers were eliminated, total workers was decreased from 19 to 16 workers.
- The output is increased by 84 pieces/shift, from 462 (60 x 7.7) pieces/shift to 546 (71 x 7.7) pieces/shift.
- The line efficiency is increased by 16%, from 67.8% to 83.8% as show fig. 10.
- The productivity is increased by 1.27 pieces/man-hour, from 462 / (19 x 7.7) = 3.16 pieces/man-hour to 546 / (16 x 7.7) = 4.43 pieces/man-hour.

5.2 Defective Reduction

Beside the sewing line efficiency improvement, the defective reduction was also performed. The Pareto analysis identified the top three causes of defective which were thread fluffy, thread loose and no red tread which were accounted for 77.2% as shown in Fig. 3. The fishbone or cause-and-effect diagram has been employed in the Kaizen activity. Fig. 11 shows the root causes obtained from the brainstorming session. The Kaizen group members composed of the representatives from production, quality assurance, and maintenance departments.

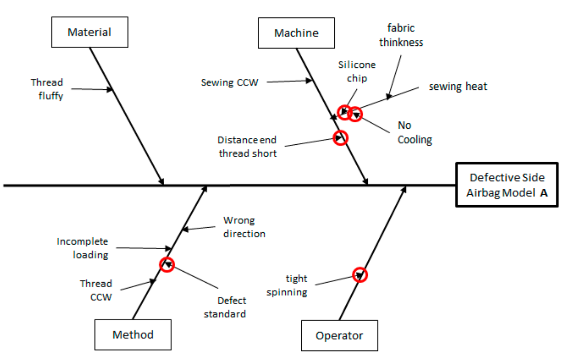

Fig. 11 The Cause and effect diagram analysis

Five factors has been selected from the cause and effect diagram and coutermeasures to reduce the defective has been identified and implemented as shown in Table 1. The results of theses countermesures reduced defective by 1.99%, from 3.07% to 1.08% as show in Fig. 12. The overall equipment effectiveness (OEE) was increased by 11.88%, from 85.06% to 96.94% as shown in Fig. 13.

TABLE I
COUNTERMEASURES AND IMPROVEMENT

Factor	Defect	Countermeasure and Improvement
No Cooling	Thread fluffy , Loose	Reduction sewing heat by added liquid Silicone lurbricant.
Silicone chip	Thread fluffy , Loose, No Red tread	Clean bobbin and hook by air gun every time when bobin changing.
Distance end thread short	No Red tread	Install thread clamping and clamp before start every time
Tight spinning thread	Thread fluffy , Loose, No Red tread	Control tight by modify manual spinning mc to automatic spinning mc.
Defect standard	All defect	Review, revise and updated defect criteria /master standard and training all concrn.

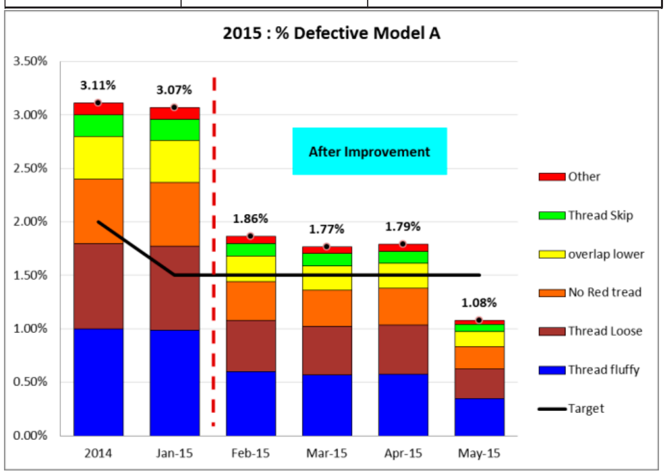

Fig. 12 Percent defective before and after improvement

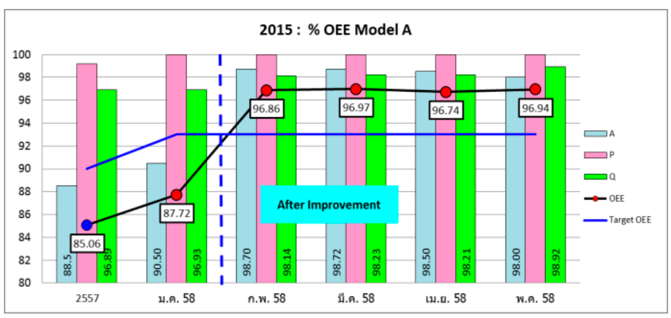

Fig. 13 Percent OEE before and after improvement

VI. CONCLUSION

The improvement results of the side airbag sewing line from this research including:

1. Elimination of 3 workers per shift from the side airbag sewing line: one from station no. 4, one from station no. 8, and one from station no. 12. The total numbers of workers are now 16 workers instead of 19 workers.

2. The output is increased by 84 pieces/shift or 168 pieces/day, from 462 (60 x 7.7) pieces/shift to 546 (71 x 7.7) pieces/shift.

3. The line efficiency is increased by 16%, from 67.8% to 83.8%.

4. The productivity is increased by 1.27 pieces/man-hour, from 3.16 pieces/man-hour (462/(19x7.7)) to 4.43 pieces/man-hour (546/(16x7.7)).

5. The defective rate is decreased by 2.03%, from 3.11% to 1.08%.

6. The overall equipment effectiveness (OEE) is increased by 11.88%, from 85.06% to 96.94%.

7. Elimination of 3 workers per shift saves 540,000 THB/year of labor cost—3 workers x 15,000 THB/month x 12 months/year.

8. Reduction of defective saves 1,512,000 THB/year—420 pieces/month x 12 months/year x 300 THB/piece.

9. The increased of output increases 13,305,600 THB/year of sale revenue—168 pieces/day x 264 days/year x 300 THB/piece.

Table 2 shows the summary results of the improvement obtained from this research.

TABLE II
SUMMARY RESULTS OF THE IMPROVEMENT

Topic	Unit	Before	After	+ / -
Worker	Labors	19	16	**-3**
Output	pieces / hour	60	71	**11**
Output	pieces / year	243,936	288,288	**44,352**
Line Efficiency	%	67.8	83.8	**16**
Productivity	pieces / man-hour	3.16	4.43	**1.27**
Defective	%	3.11	1.08	**-2.03**
OEE	%	85.06	96.94	**11.88**
A: Availability	%	88.5	98	**9.5**
Q: Quality	%	96.89	98.92	**2.03**
Labor Cost	THB / year	3,420,000	2,880,000	**-540,000**
Defective Cost	THB / year	2,278,800	766,800	**-1,512,000**
Sale income	THB / year	73,180,800	86,486,400	**13,305,600**

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