The Usage of Overall Equipment Effectiveness in Measurement to Improve Efficiency and Increase Productivity of Process for Packaging Cigarettes

Bunsong Khamon

Department of Industrial Engineering, Faculty of Engineering
Ramkhamhaeng University, Bangkok, 10240, Thailand

Email: bunsong4051@ru.ac.th

Abstract The purpose of this research is to improve efficiency and productivity of production process of cigarettes of factory 5 by select the packing process cigarette 2 to study, and use the Overall Equipment Effectiveness (OEE) in measurement to improve. The results of the study showed the main cause of Overall Equipment Effectiveness and productivity was declined including organizing and labor, machinery, raw materials. The proposed guidelines of improvement are as follows. (1) Organizing and Labor, including the Job duties and responsibilities must be clearly identified. Staff training to improve their knowledge and expertise must be provided. (2) Machinery, including implementation of Total Productive Maintenance (3) Raw materials, including discovering the appropriate conditions of cigarette packing method by the experiment of central composite design. After the application of the mentioned method, showed the Loading Efficiency Index value was higher to 92.59%, the Machine Efficiency Index value was up to 84.17% and the Quality Rate Index value was increased to 98.88% as a result, the Overall Equipment Effectiveness increased from 51.05% to 77.07%, production efficiency was increased from 52.27% to 79.66% and productivity was increased from 9,899 packs per hour to 15,058 packs per hour or was increased to 52.12%

1. Introduction

[1] In any business we have to produce with quantity, quality and cost set by production standards. The sample factory that is the cigarette industry is experiencing productivity quality problems and falling productivity. It's cause of increase of cost, due to overtime to increase the number of planned production. Sometime cigarettes out of stock make lack of customer trust. So that the factory have to continuous improvement and development follow corporate development strategy year 2017-2021. By the aim to improve efficiency and increase effectiveness, personnel development and organization. Improve product quality, develop new production. In order to meet the purpose of the sample factory as a guideline to follow the plan to improve efficiency and increase effectiveness, so that the research was conducted. Based on a retrospective study of fiscal year 2016, found that the amount of output at normal working hours the average was relatively low 61.02% compared with the planned production volume. Plan division was set the output target not less than 90%.

This research has chosen the packing process cigarette 2 from factory number 5 to study because of manufacturing process was bottleneck, include low efficiency and low productivity to study to guide to improve the efficiency and productivity following the target.

2. Objective

To improve the efficiency and productivity process of packing cigarette 2 of factory number 5 by using the overall effectiveness value of the machine is a measure of improvement by setting production increase efficiency targets of not less than 75% when compared with the planned production amount.

3. Research Methodology

3.1 General information of the sample factory
The sample factory has 3 factories and produce brands of filter cigarettes is divided into 17 brands for the example Kor. 90 and Kor. American Style and Kor. Light. And produce non-filter cigarettes 5 brands such as Kor. 33, Sor. 33 and Ror. 33 etc. Based on the previous information of fiscal year 2012-2016 was found that production capacity is about 5,614.18 million roll per year. The production details are as following the factory no. 3 was produced about 3,099.59 million roll cigarettes per year accounted for 55.21%. Factory no. 4 was produced about 1,492.81 million roll cigarettes per year accounted for 26.59% and factory no. 5 was produced about 1,021.78 million roll cigarettes per year accounted for 18.20%. This research brings previous fiscal year 2016 data to study, it was found that the production of factory no. 5 was a low performance on the average 57.27% compared with the planned production amount. So that we choose factory no. 5 to study because of the minimum efficiency. which is a cigarette factory with modern machinery that the process of producing cigarettes is divided into two parts. Such as tobacco manufacturing process, roll and packing processes. Tobacco manufacturing process is the responsibility of the tobacco division. Start from the preparation of raw materials, the process of roll and packing cigarettes is the duty of the roll and packing division. Takes duty to receive tobacco from tobacco division by the suction pipe into the roll machine and processed tobacco into cigarettes.

3.2 Analyze the problem of the process
Based on the study of production conditions of factory 5 have two processes of cigarette production. It was found that the process of producing cigarettes is a bottleneck from the process of packing the cigarette into the package. From the data collection between October and November 2016, it was found that the process of packaging cigarettes 2 lowest performance. The average equal 1.96 million packs per month compared with the planned production was 52.27% and the average was 9,899 packs per hour. Which is the efficiency and productivity are low this process uses the cigarette packaging process 2 as a sample process. To improve and guide to increase the effectiveness of cigarette production.

3.3 Analysis of the causes of decline productivity
From the study process of packing a cigarette 2, it has been found that the main reason of the efficiency and productivity falling down. The cause of organization and labor, the cause machine and raw material reasons.

3.3.1 Analyzing the causes of organization and labor from the study of the organizational structure of the roll and packing department. Found that not used the organizational chart officially, made lack of clear flow of work order, lack of follow-up control and evaluation. **[2]** Which is the principle of corporate management. Summarize causes of current organization and labor as a guideline for improvement as the following

1) Lack of communication and coordination between agencies.
2) Lack of used formal organizational charting or written assignments to assign supervisory lines and description of each position.
3) Staff lack training support to make their work more efficient.

3.3.2 Analysis cause of machine manufacture of cigarettes, the department of roll, packing and boxes packing are the main machine. Due to the manufacturing process, the cigarette produces was bottleneck at the packing with packing machine. From the study have collected the information about the loss of cigarette packing machine in terms of time, performance and quality. This will be used as a performance index of indicator loss as Loading Efficiency, Machine Efficiency, Quality Rate and Overall Equipment Effectiveness. **[3]** definition of OEE that Total Productive Maintenance: TPM is OEE it include operations, maintenance, and management of tools and Overall Equipment Effectiveness (OEE) it is a measure of efficacy and effectiveness of machine operation by the equation is calculated as follows: OEE = Loading Efficiency (%) $\times$ Machine Efficiency (%) $\times$ Quality Rate (%)

3.3.3 Raw material analysis, raw materials used to produce cigarettes of roll and packing department to become cigarette are divided into two categories as tobacco and wrappers, tobacco are ingredients that are cut into striated and through the process of preparation of the tobacco division. The wrapped material are rolling paper, filter paper, Rolling seam adhesive paper wrapper, glue stick etc. Sometimes, when the glue or some materials such as seam pack butts, filter paper, but not used properly. That the filter removes from the cigarette. The pack seam breaks apart. This is the main causes a loss of time and quality. Due to the adhesive material parameters seam the pack and improper parameter setting of the cigarette packaging machine. From data collected since October to November 2016 showed that on average, the proportion loss is 0.0597. Limited target to reduce of broken seam pack 70% by starting from the assessment of the stability of the process packing cigarette. Which is in control or not, and **[4]** configured to test data abnormality on the control chart by reference the United States Automotive Industry Data Abnormality Test (AIAG). Based on the analysis of proportional control charts. The loss contains all the data that plot on the control chart in the line control and the information is random. It can be concluded that the proportion of loss and stability of the process is stable and the data is random. So the problem was analyze and modified.

3.4 Improving efficacy production process

3.4.1 Organizational and Labor Improvement. In implementing the improvement was taken organizational structure of roll and packing department is used officially or written in writing. Then doing a job description of each job is provided let each person know the role of the job by identifying position name, the duties and responsibilities of each position clearly and training staff to increase their expertise.

3.4.2 Machine improvement

Roll and packing department in the manufacture of cigarettes are mainly used machines which high cost imported from abroad its lifetime over 10 years. For this reason, it is important to keep maintenance machinery as specially. Especially in the process of roll cigarette to packing as the bottleneck of the production process Therefore**, [2]** take maintenance techniques by used TPM for all participant to apply to improve. In order to Applying this technique. Starts with the management to support and accept the technique first. After that sub-group activities will be established in the production process. Then embark on the following 4 steps as the following

1) Determine the area and set up a team to improve.
2) Basic knowledge training required for the concerned person
3) Gather data and issues before improve then present to team members, develop team and maintenance teams to know by yourself to understand and solve the problem of the production process.

4) Apply TPM techniques to solve problems of production lines after that, each group presents the results which is applied to the management team.

3.4.3 Raw material improvement

Based on the raw material analysis it was found that the raw materials used packing had problems in quality and standard of parameters material of adhesive seam of pack. Including to parameter adjustments the appropriate of the packing machine. Because the parameters are very effective for process of packing a cigarette. From the problem of parameters standard, this research will study the appropriate parameters. The process of packing a cigarette by experiment design the steps are as following.

3.4.4 Analysis of characteristics and causes of loss

From the data collection Between October and November 2016, the average of productivity was 1.96 million packs per month. The amount of loss is 0.117 million packs per monthly. Accounted for the proportion of loss ratio of 0.0597 or 5.97% They can be classified by loss type as following (1) The pack seams was broken 97,660 packs cigarettes, accounting for 0.8347 (2) Cigarettes was broken and no filter bottoms, 19,040 packs, accounted for 0.1627 of all loss. Based on the information, there are a lot of loss in broken seam pack, **[5]** therefore we used designed 2^k Factorial and Central Composite Design to applied in order to decrease the loss of broken seam package 70%. By starting to find the cause of package seam broken from brainstorming of people involved in the process of producing cigarettes. Using the cause and effect diagram, to know the cause of the problem is identified. Summarized as following

1) Moisture of tobacco at present the tobacco room sets the standard moisture content of cigarettes at 12%
2) Current adhesive material used the standard is to set the glue quantity at 40% stickiness 1800 - 3500 Cps at 27 ± 2 ℃.
3) The current speed of the packing machine is 300 pack per minute
4) The temperature of the seam packing currently sets the standard temperature at 200 ℃.
5) The pressure seam adhesive of packing at the present set at 5 psi and wrapper type C.

The researcher and the improvement team brainstormed and considered together and prioritized the cause of the loss by using process analysis techniques, **[6]** the form of loss and process effects (Process FMEA). The result of the analysis that conclude the number of risk levels (RPN) are in descending order. Such as the temperature of the seam packing is 648. The adhesive material (% adhesive) is 504. Pressure adhesive seams have a value of 343, the humidity of the tobacco is 86, and the wrapping paper has a value of 75, respectively. The speed of the cigarette packing machine cannot be considered due to the productivity. This research has introduced the factors that affect the loss that have a higher risk than the 100 value to study such as the temperature of the seam packing machine for packing seam, types of glue, pressure adhesive, Experimental control variables is moisture of tobacco is maintained at 12%. The speed of the packing machine remains at 300 pack per minute and wrapped paper still use as the type C. Because the researcher and the improvement team found that it was not the effective of loss the experiment was set up and controlled as described above.

3.4.5. Determination of suitable conditions by experimental design.

Experimental design by use two factorial model with 2 levels (2^k Factorial) This step is a preliminary experiment with two factorial design techniques with 2 level that have increasing center in order to determine these three factors affect with loss in any form. After screening Factor with FMEA technique from the researcher and the team has improved, that should be define the following factors: Factor A is the temperature seam pack with 2 level: Low (180 ℃) and High (220 ℃). Factor B is the pressure seams was set with 2 levels: Low (4 psi) and High (6 psi). Factor C is adhesive material was set a two-level: Low (glue 30%) and High (glue 50%). Researchers and team provided factor for experimentation and control of variables in the experiment response variable, **[7]** Proportion of loss of each run will be randomly measure of sample size as $n = \left(Z_{1-\alpha/2} + Z_{1-\beta}\right)^2 / N\delta^2$ by Power = 0.90 and Alpha = 0.05, Calculation Units per run = 354 packs, To avoid too many zeros to user Units

per run = 400 packs then bring the value to be converted to the defect proportion. The results of 2 level factorial experiments as shown in Table 1.

Table 1. Session analysis Factorial Fit: defect proportion versus A (temperature), B (pressure), C (adhesive). Estimated Effects and Coefficients for defect proportion (coded units)

Term	Effect	Coef	SE Coef	T	P
Constant		0.05304	0.000082	649.57	0.000
A (temperature seam)	-0.02792	-0.01396	0.000082	-171.01	0.000
B (pressure)	-0.00522	-0.00261	0.000082	-32.00	0.001
C (adhesive)	-0.01243	-0.00621	0.000082	-76.09	0.000
A (temperature seam) * B (pressure)	-0.00893	-0.00446	0.000082	-54.65	0.000
A (temperature seam) * C (adhesive)	0.00508	0.00254	0.000082	31.08	0.001
B (pressure) * C (adhesive)	-0.00162	-0.00081	0.000082	-9.95	0.010
A (temp.) * B (pressure) * C (adhesive)	0.00357	0.00179	0.000082	21.89	0.002
Ct Pt		-0.00207	0.000156	-13.25	0.006
Curvature					0.006
S = 0.000230940 R-Sq = 100.00% R-Sq(adj) = 99.98%					

Table 1: Results of the Experimental Analysis on Session to find out what factors influence the process which use the p-value from the Estimated Effects to choose which factors have a significant influence This research determined the significance level of 0.05 The three main factors were Factor A (temperature seam), Factor B (pressure) and Factor C (adhesive). As well as the joint influence between Factor A(temp.seam)*B(pressure), A(temp.seam)*C(adhesive), B(pressure)*C(adhesive), A(temp.)*B(pressure)*C(adhesive). Significant statistical influence. Because the p-value is less than 0.05.

3.4.5.1. Central Composite Design: CCD

Table 1: Center Point (Ct Pt), Curvature, P-value less than 0.05 show that the variables studied have linear curvature relationships. **[8]** Therefore use the design of the CCD experiment this is an experimental for studying variables with linear curvilinear relationships but the number of Runs is not much, and additional experiments from 2^k Factorial. Therefore, the main factors affecting the three response variables are temperature seam, adhesive, pressure to analyze and design experiment. In order to try to find the nearest point with to the best production by additional experiments were conducted using the base of the 2^k Factorial. To find the optimal factor level that minimizes the amount of waste that occurs in the process and set α at 0.05. Which can display level of factor, experimental results, Analysis of Variance for defect proportion, and Show relationships that affect the proportion of loss (Estimated Regression Coefficients for defect proportion using data in uncoded units) as shown in Tables 2, 3, 4 and 5 respectively.

Table 2. Factor level of Central Composite Design

Factor	Symbol	Factor Level					Unit
		-α	-1	0	+1	+α	
temperature seam	A	166	180	200	220	234	degree Celsius
pressure	B	3.3	4	5	6	6.7	psi
adhesive	C	23	30	40	50	57	Percent

Table 3. Experiment result (CCD)

Factor A temperature seam	Factor B pressure	Factor C adhesive	defect proportion
180	4	30	0.0713
220	4	30	0.0508
180	6	30	0.0802

220	6	30	0.0347
180	4	50	0.0590
220	4	50	0.0415
180	6	50	0.0575
220	6	50	0.0293
200	5	40	0.0511
200	5	40	0.0507
200	5	40	0.0511
166	5	40	0.0727
234	5	40	0.0304
200	3.3	40	0.0500
200	6.7	40	0.0453
200	5	23	0.0682
200	5	57	0.0484
200	5	40	0.0479
200	5	40	0.0536
200	5	40	0.0508

Table 4. Analysis of Variance for defects proportion

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Blocks	1	0.000002	0.000001	0.000001	0.10	0.754
Regression	9	0.003361	0.003361	0.000373	62.72	0.000
Linear	3	0.003013	0.003013	0.001004	168.69	0.000
A (temperature seam)	1	0.002448	0.002448	0.002448	411.15	0.000
B (pressure)	1	0.000061	0.000061	0.000061	10.20	0.011
C (adhesive)	1	0.000504	0.000504	0.000504	84.72	0.000
Square	3	0.000131	0.000131	0.000044	7.36	0.009
A (temp_seam) * A (temp_seam)	1	0.000000	0.000001	0.000001	0.25	0.632
B (pressure) * B (pressure)	1	0.000026	0.000016	0.000016	2.70	0.135
C (adhesive) * C (adhesive)	1	0.000105	0.000105	0.000105	17.64	0.002
Interaction	3	0.000216	0.000216	0.000072	12.10	0.002
A (temp_seam) * B (pressure)	1	0.000159	0.000159	0.000159	26.76	0.001
A (temp_seam) * C (adhesive)	1	0.000052	0.000052	0.000052	8.65	0.016
B (pressure) * C (adhesive)	1	0.000005	0.000005	0.000005	0.89	0.371
Residual Error	9	0.000054	0.000054	0.000006		
Lack-of-Fit	5	0.000037	0.000037	0.000007	1.82	0.291
Pure Error	4	0.000016	0.000016	0.000004		
Total	19	0.003416				

S = 0.00244004   R-Sq = 98.43%   R-Sq(adj) = 96.69%

Table 5. Estimated Regression Coefficients for defects proportion using data in uncoded units

Term	Coef
Constant	0.1305060
Block	0.0001782
A (temperature seam)	-0.0003809
B (pressure)	0.0563581
C (adhesive)	-0.0049039
A (temperature seam) * A (temperature seam)	0.0000008
B (pressure) * B (pressure)	-0.0010592
C (adhesive) * C (adhesive)	0.0000271
A (temperature seam) * B (pressure)	-0.0002231
A (temperature seam) * C (adhesive)	0.0000127
B (pressure) * C (adhesive)	-0.0000813

3.4.5.2 Summary of Central Composite Design
From Table 4, the results of Central Composite Design it was found that the temperature seam, pressure, adhesive, (adhesive)*(adhesive), (temperature seam)*(pressure) and (temperature seam)*(adhesive) the p-value is less than 0.05. It can be concluded that these factors affect the amount of loss in the cigarette packing process. And the P-value of Lack-of-Fit is 0.291 this is more than the significance value level 0.05. Means a regression model for the loss proportion is appropriate Significantly, by R-Sq (adj) = 96.69%.Thus, a regression model was developed for the waste proportion as equation (1) and check the statistical hypothesis by graph Residual Plots that not found conflict with the statistical assumptions.Table 5 shows the relationships that affect the proportion of loss and it can be modeled regression equation that shows the relationship between various factors. Which influence on the proportion of loss. As equation using data in uncoded units (1)

$$Y_{(minimum)} = 0.130506 - 0.0003809(temp\_seam) + 0.0563581(pressure) - 0.0049039(adhesive)$$
$$- 0.0002231(temp\_seam)*(pressure) + 0.0000127(temp\_seam*(adhesive)$$
$$+ 0.0000271(adhesive)*(adhesive) \qquad (1)$$

3.4.5.3 Determining the optimal factor value from the experiment
Based on the equation (1), find the proportion value of loss generated by the experiment analysis with the Response Optimizer will be get the best appropriate values for all three factors are shown in Figure 1.
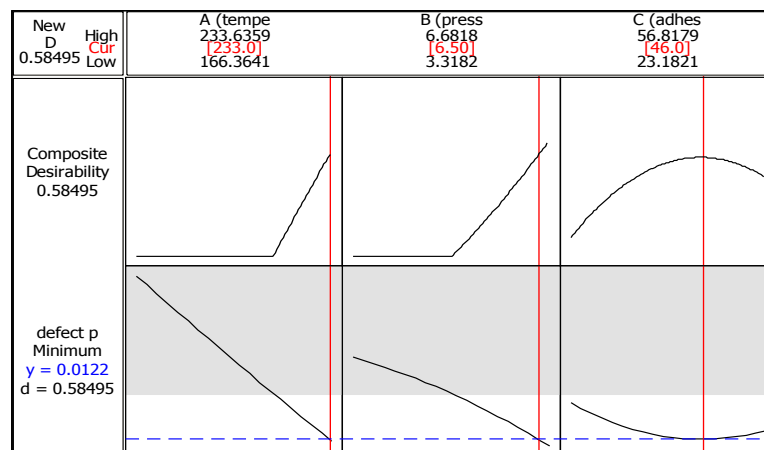

Figure 1 Optimization plots for the tire data, the current factor settings are temperature = 233 ℃, pressure = 6.5 psi, and adhesive = 46%, the goal was to target minimum at 0.0122.

3.4.5.4. Summary of experimental results
The conclude results of this experimental design used the experimental analysis on the Session. Helps to translate the Influenced of the main factors and influenced by common factors as shown in Table 4, and find the appropriate factor is shown in Figure 1. If the process of producing cigarette 2 step the packing using the temperature seam packing 233 ℃, pressure 6.5 psi, and the adhesive material has an adhesive content of 46% it has the lowest loss ratio of 0.0122.

4. Results
Application of methods to improve the efficiency packing cigarette. After applied the results to the production of packing process cigarette 2 between July and August 2017. Found that (1) organization and labor have study and improve the structure organizations and labor, by adopting a formal organizational chart or writing. To have a clear flow of work order, and set the scope of duties or job characteristics to do of each position clearly in order to control work monitoring and evaluation as well as educate staff by training. The cigarette packer did not receive the load because it was waiting to be transported to ten packets it decreases from 765 minutes were 167.5 minutes or decreased

78.11%. (2) Machine used TPM technique to increase productivity can be summarized after the improve as the following, The average monthly loss of the packing machine was reduced from 1,117.5 minutes to 587.5 minutes, or a decrease of 47.43%, the average time of loss per month of packing machine was reduced from 2,163 minutes to 2,008 minutes or 7.17%. (3) Raw material can be summarized after the improve as the following: time lost with the packing machine does not get the work load due to raw materials defects and package seams was broken, the monthly average decreased from 672.5 minutes to 91.5 minutes decreased by 86.39%. And the proportion of loss package seams was broken average monthly decreased from 0.8347 to 0.2177, a decrease of 0.617 or decreased 73.92%, the overall loss content of cigarette packaging and roll production process 2 decreased from 0.0597 was 0.0111, decreasing 0.0486.

5. Conclusion & Recommendations

Conclusion the study result by use the Overall Machine Effectiveness (OEE) measure to improve efficacy and increase the productivity of the process packing cigarette 2 of factory number 5. Index of indicators in this study include Loading of machine speed, efficacy of machine and the quality rate has increased. As well as the overall effectiveness of the machine has also increased when compared with the index value before improve. It was found that the average value of Loading efficiency increased by 17.35% with a value of 92.59%. Machine efficiency increased by an average of 12.03% to 84.17%. The quality rate increased on average by 4.83%, to 98.88%, and the overall effectiveness of the machine has increased by an average of 26.02% the value is 77.07%. by adding these index. As a result, production efficiency increased from 52.27% to 79.66% and productivity increased from 9,899 packs per hour to increase to 15,058 packs per hour or increased to 52.12% of the original yield. the method applied to optimize the production process of packaging cigarettes can be reduce the losses. And increase the efficiency of the production process of packaging cigarettes is higher than 75% according to the target. In order to applied this approach production process of packaging cigarettes of other units for further efficiency. Should be study to increase the high efficiency of the machine. Because the researcher also sees that there are ways to increase the efficiency of the packing machine by reducing the loss of capacity of the time machine. Which is as high as 2,008 minutes.

References
[1] Wanchai Rijiravanich 2000 Productivity in the industry (Bangkok: Chulalongkorn University)
[2] Chitra Rukijkanpanich 2001 Management of maintenance (Bangkok: Chulalongkorn University)
[3] Dal B, Tug well P and Greatbanks R 2000 Overall equipment effectiveness as a measure of operation Improvement *International Journal and Production Management*, 20(12), pp 1488–1502
[4] Douglas C Montgomery et al 2011 *Inc* Statistics for Engineering (N.Y.: John Wiley & Sons)
[5] Parames Chutima 2004 The experimental design engineering (Bangkok: Chulalongkorn University)
[6] Tejaskumar S Parsana and Mihir T Patel 2014 A Case Study: A Process FMEA Tool to Enhance Quality and Efficiency of Manufacturing Industry Bonfring *International Journal of Industrial Engineering and Management Science* vol 4, no 3 pp 145-152
[7] Bisgaard S and Fuller H T 1995a sample Size Estimates for 2k-p Design with Binary Response *Journal of Quality Technology* vol 27, no 4 pp 344-354
[8] Douglas C Montgomery 2005 *Inc* Design and Analysis of Experiments vol 6, ed (The United States of America: John Wiley & Sons)