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Operational Efficiency Improvement of Ply Cutting Machine for Aircraft Tires

Operational Efficiency Improvement of Ply Cutting Machine for Aircraft Tires

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Abstract. This research focuses on the operational efficiency improvement of ply cutting machines for aircraft tires by implementing the design of experiments (DOE) and Single Minute Exchange of Die (SMED) methods to decrease loss time caused by machine stoppages found at let-off and splicer processes. The problem comes from high loss time because the system's parameters are not set properly and high setup time of the machine. Therefore, the operations efficiency improvement has been conducted by setting a suitable flow rate at the splicer and changing activities of the operator in order to reduce waiting time. Improved efficiency is implemented in the Ply cutting machine from July 2018 to August 2018. The result shows the increase in the average production from 23 rolls/shift to 28 rolls/shift. Furthermore, a cost saving for efficiency improvement is equal to 36M baht per year.

1. Introduction

Ply is component in aircraft tire, it is produced by the semi-auto machine. A study is one of cutting machine, its production begins by receiving master roll until sent good component to tire building machine. Ply cutting machine consist of two let off, one cutter, two tables of the splicer and two wind up post. The flow of the ply cutting machine as shown in Figure. 1.

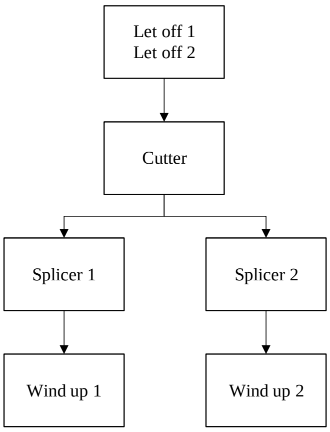

Figure. 1. Flow of Ply cutting machine.

Loss time was found at let off and splicer process that was impacted to production because they stopped the machine for change size at let off and waited on a wind-up process for folding ply out of the sensor. It made high waiting time. Often, production does not achieve production capacity's target per shift. Production data for Ply cutting machine from July 2017 to June 2018 shows the average of production per shift equal to 23 roll/shift as shown in Figure. 2

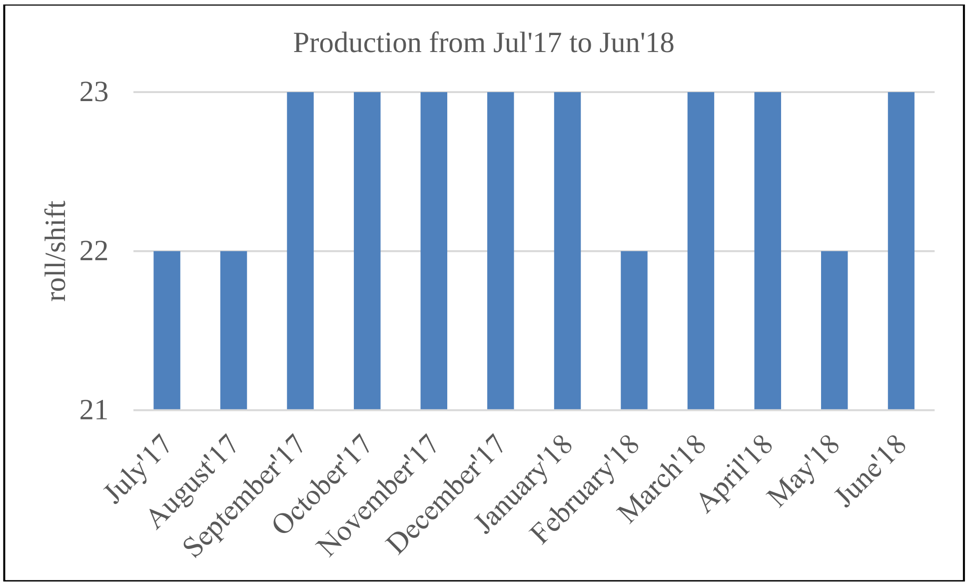

Figure. 2. Actual Production of Ply cutting machine.

2. Problems

Focusing on Ply cutting machine, Pareto chart of cutting ply makes researcher realize that the root cause of low production because of high waiting time in the current. Currently, the table of the ply cutting machine has two positions for load small roll, splicer and unload small roll but have no operator for load master roll at let off during the process. The average three main waiting times from July 2017 to June 2018 are as follows: waiting for loadmaster roll at let off, waiting for splicer and waiting time for machine breakdown. Their waiting times equal to 81%, 8%, and 4%, respectively, as shown in Figure. 3.

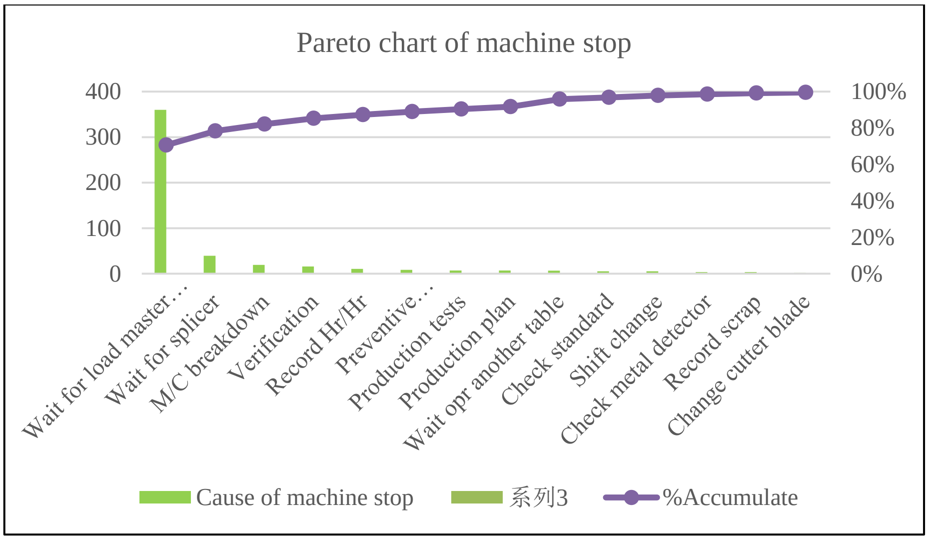

Figure. 3. Pareto chart of machine stop.

3. Process Improvements

Wastes removal tool based on Design of Experiment (DOE) and Single Minute Exchange of Die (SMED) were used to improve the efficiency of operation of Ply cutting machine. There were totally two approaches to improve efficiency as follow

3.1. Improving the Working Method

The objective was to reduce waiting time of machine from internal setup to external setup by applying Single Minute Exchange of Die method (SMED) [1] to separate internal and external setup, converting internal to external setup and streamlining all aspects of setup operation. All of the setup activity as shown in Table 1. This simulation result need to increase one man per shift for external setup activity in order to achieve customer demand in AC 2019 and compare opportunity cost and labor cost as shown in Table 2.Therefore reduce waiting time after improvement production are 27 roll/shift and average operator workload is 90.6% as shown in Table 3, increase from the original 23 rolls/shift.

Table 1. The activity of setup machine.

Activity	Total time (min/shift)
Bring master roll to post by forklift	8
Drive forklift to machine	16
Unpack master roll	5
Load master roll to let off	33
Unload liner master roll	9
Load empty core to let off	13
Unload core master roll	5
choose master roll from storage area	13
Keep empty container to area	10
Total	113

Table 2. Compare opportunity cost and labor cost.

Cost	M THB/year
Opportunity Cost	38
Labor cost	2

Table 3. Actual production for a shift.

Machine	Target (roll/shift)	Actual production (roll/shift)	Workload (%)
Splicer table1	14	14	93.79%
Splicer table2	13	13	87.43%
Service opr	-	-	95.12%

3.2. Improving Process of the Splicer

The objective was to optimize the parameter settings of splicer process for splicing Ply and returning to an original position with staffs have to manual move ply out of splicing path every time after splicing finish, which is a waste that occurs in the process. Therefore, the concept of the setting parameter was used to solve the problem by applying DOE. The experimental design method was adopted to find the factors that show the statistically significant effect on the cycle time. Three factors were experiments including splicer temperature, air pressure, and flow rate. The 2K full factorial design [2] with 3 factors, 2 levels and 2 replicates of each factor were adopted to test whether or not the main effects and their interactions were significant as shown in Table 4.

Table 4. Factors and levels in 2^K full factorial design.

Factors	Unit	Symbols	Levels of factor	
			Low (-1)	High (1)
Temperature	Celsius	A	80	100
Pressure	Bar	B	3	4
Flow rate	m^3/min	C	1	1.5

The experimental data were analyzed by using the Minitab software [3]. From the Pareto chart of effects as shown in Figure. 4, the factor effect with its value greater than 2.31 is a significant factor at 95% confident interval equal. The Pareto chart of effect showed that the main effects C have P-values less than 0.05 (significant level α), whereas factor A and B and interaction (AB, AC, BC, and ABC) were not significant. Therefore, it can be concluded that the main effects C are significant at 95% confident interval. As a result, all significant factors need further investigation to find their appropriate level setting.

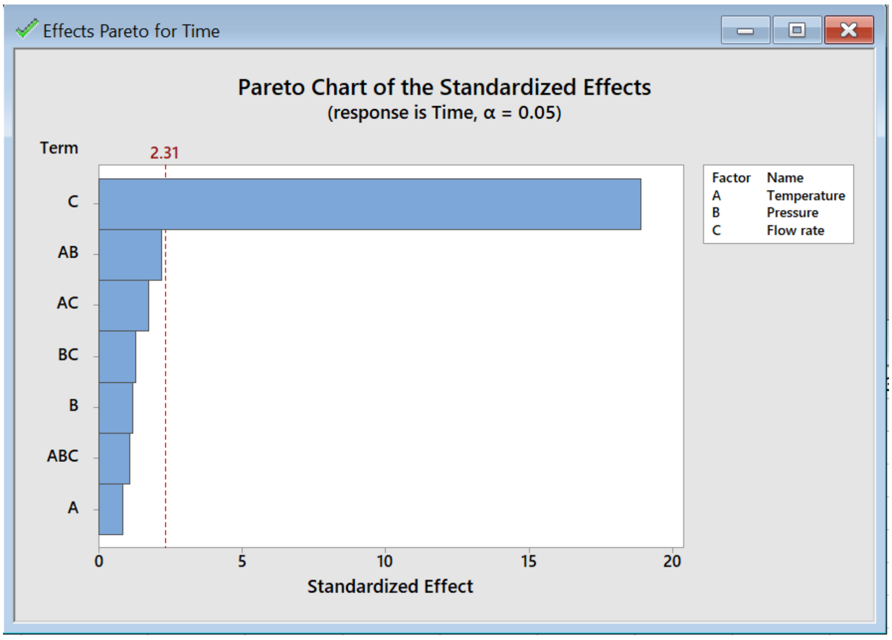

Figure. 4. Pareto chart of effects.

4. Results

The 2^K full factorial experiments were tested to find their appropriate setting parameter that can reduce the waiting time of the splicing process. The statistical analysis showed that the main effect obtained the p-values of less than 0.05 as shown in Figure. 5. Therefore, it can be concluded that the main effect affected the cycle time at 95% confident interval. Since the main effect was used as a mean to select the proper setting for factors, factor C was set at 1.5 m^3/min (high level of factor C) as shown in Figure. 6 and production increased 1 roll/shift.

Factorial Regression: Time versus Temperature, Pressure, Flow rate

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	7	73.5044	10.5006	53.00	0.000
Linear	3	71.3969	23.7990	120.12	0.000
Temperature	1	0.1406	0.1406	0.71	0.424
Pressure	1	0.2756	0.2756	1.39	0.272
Flow rate	1	70.9806	70.9806	358.26	0.000
2-Way Interactions	3	1.8819	0.6273	3.17	0.085
Temperature*Pressure	1	0.9506	0.9506	4.80	0.060
Temperature*Flow rate	1	0.6006	0.6006	3.03	0.120
Pressure*Flow rate	1	0.3306	0.3306	1.67	0.232
3-Way Interactions	1	0.2256	0.2256	1.14	0.317
Temperature*Pressure*Flow rate	1	0.2256	0.2256	1.14	0.317
Error	8	1.5850	0.1981		
Total	15	75.0894			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.445112	97.89%	96.04%	91.56%

Figure. 5. Result of ANOVA.

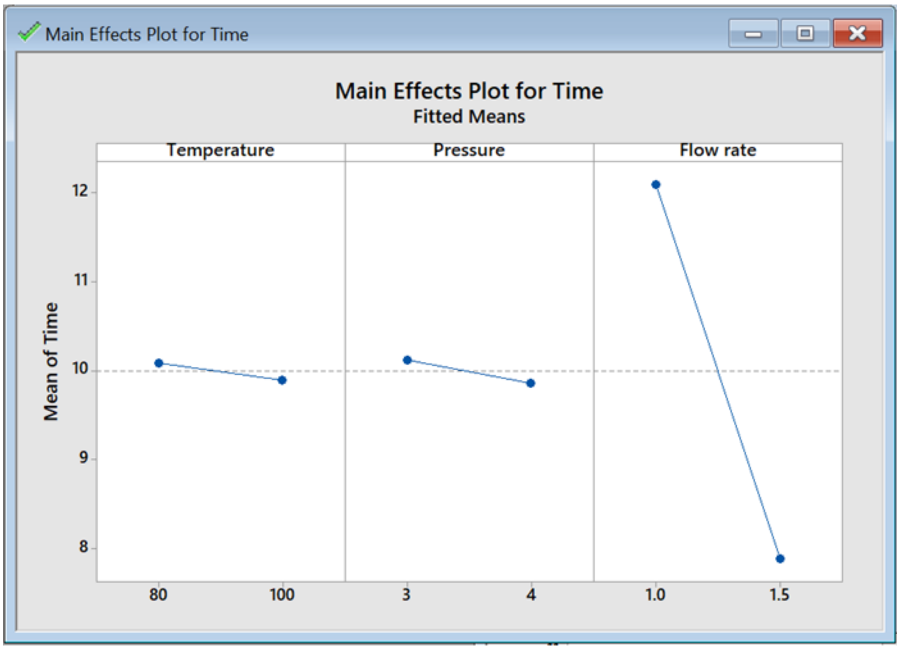

Figure. 6. Main effects plot.

5. Conclusions

The objective of this research was to apply the Design of Experiment (DOE) and Single Minute Exchange of Die (SMED) to improve the efficiency of ply cutting machine caused by waiting time. DOE and SMED were systematically utilized to find the appropriate factor which was needed to improve. Production's result after implementing the new organization for external setup machine and setting flow rate from July 2018 to August 2018 is increased as expected. The production increased from 23 rolls/shift to 28 roll/ shift and cost-saving equal to 36M Baht per year.

6. References

[1] Information on https://www.leanproduction.com/smed.html
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