

Quality Control of the Steel Wire Rod Product by Integration Lean Six Sigma and Taguchi Method

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Abstract. RMW Inc. is the global company in Indonesia. One of its product is the steel wire rod. This research aims to control the production process and improve the product quality. This research is using the integration between lean six sigma and taguchi method. The first step is to reduce the waste using lean six sigma method while the second step is to reduce the defect using taguchi method. Based on the identification of seven waste, the most dominant waste is the defect that is caused by there is no setting of the roll entry guide. The product has 11 CTQ (critical to quality) with the focus on laps defect, underfill defect, and overfill defect. Then, the cause of failure is identified using FMEA (failure mode effect analysis). The level of sigma capability is achieved at 4.54 with DPMO (defect per million opportunities) is 4006.55. The first improvement can reduce the time until 8.9 minutes. The second improvement sets the roll entry guide. The optimum factors for setting of the roll entry guide is A factor with 150 tonnages of wear level, C factor by 5 bar of cooling and D factor by 6 ml of lubrication.

1. Introduction

1.1 Background

RMW Inc. is a steel company consisting of several factories. One of the factory is the wire rod steel. Over the past few years, RMW Inc. often perform production processes resulting in waste and declining product quality. SWRM 8 is the product that has the largest number of defects compared to other grades. The total defect of SWRM 8 is 404 coils of total production of 100959 coils. Improving the quality and control of production processes needs to be done continuously by eliminating waste to produce optimal production process and reduce the defect of steel wire rod products SWRM 8.

Many researchers have developed lean six sigma in manufacturing companies [13,14,2]. At the same time, some researchers have investigated taguchi method in manufacturing companies [17,16,18,15]. The integration of lean six sigma methodology and taguchi method has not yet considered by previous studies.

Based on the problems contained in the wire rod steel factory of RMW Inc. and previous studies, this research proposes to build a model of quality control that integrates a lean six sigma methodology with taguchi method to control and improve the production process and the product quality in manufacturing companies.

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1.2 Research Objectives

Based on the formulation of the problems, the purpose of this study are as follows:

1. Identify the waste contained in the production process of SWRM 8 in the wire rod factory of RMW Inc.
2. Identify factors causing defects in SWRM 8 products.
3. Determining the level of sigma capability in the production process of SWRM 8 products.
4. Designing proposed improvements to the production process of SWRM 8 products.
5. Determining the optimum factors to minimize the potential failure of the product.

2. Literature Review

2.1 Lean

The concept sourced from the National Institute of Standards and Technology (NIST) in the United States states that, lean is an approach used to identify and eliminate activities that do not add value (waste) continuously by distributing products only to increase consumer needs [4].

2.2 Seven Waste

According to [9], waste in Toyota's production system has seven types consists of over production, waiting, transportation, unnecessary inventory, unnecessary motions, and defects. Waste consists of three different types of activities that occur in the production system operations performed:

1. Value added
All activities that produces products or services that provide added value for consumers, then consumers are willing to pay for the activity.
2. Necessary non value added
Any activity that produces products or services that do not add value to the consumer but is required and under current operating procedures, unless there is a change in the existing process.
3. Non value added
All activities that produces products or services that do not provide added value for consumers.

2.3 Value Stream Mapping (VSM)

Value stream mapping (VSM) is a mapping method that shapes the flow of the value of the production process from the initial arrival of the raw material (supplier) to the output and customer. The VSM is made in detail to identify and eliminate waste, and also to improve the flow of production process [2].

2.4 Six Sigma

Six Sigma Methodology is a vision of quality improvement towards the target of 3.4 failure per million opportunities (DPMO) for each product transaction, goods or services [11]. According to [10], there are five steps for implementation of quality improvement with six sigma method using DMAIC (define, measure, analyze, improve, and control). Control stage as continuous process control to improve process capability toward six sigma target [1]. Lean six sigma is a combination of lean concept and six sigma methodology [11].

2.5 Failure Mode and Effect Analysis (FMEA)

FMEA is a methodology used to evaluate failures occurring in a system, design, process, or service [3]. Failure mode and effect analysis (FMEA) is a procedure to identify and prevent the failure of a product so that the output of the production can meet company standard [5]

2.6 Taguchi Method

Taguchi method is a methodology in the engineering field that aims to improve the quality of products and processes and can reduce costs and resources to a minimum. The target of taguchi method is to make the product robust to noise, because it is often referred as robust design [8].

3. Research Methods

This research using integration of lean six sigma and taguchi method. The lean six sigma is required to reduce the waste and the Taguchi method to reduce the defect, one of the seven waste based on Toyota’s production System.

The flow of research is shown in the figure 1 as follow:

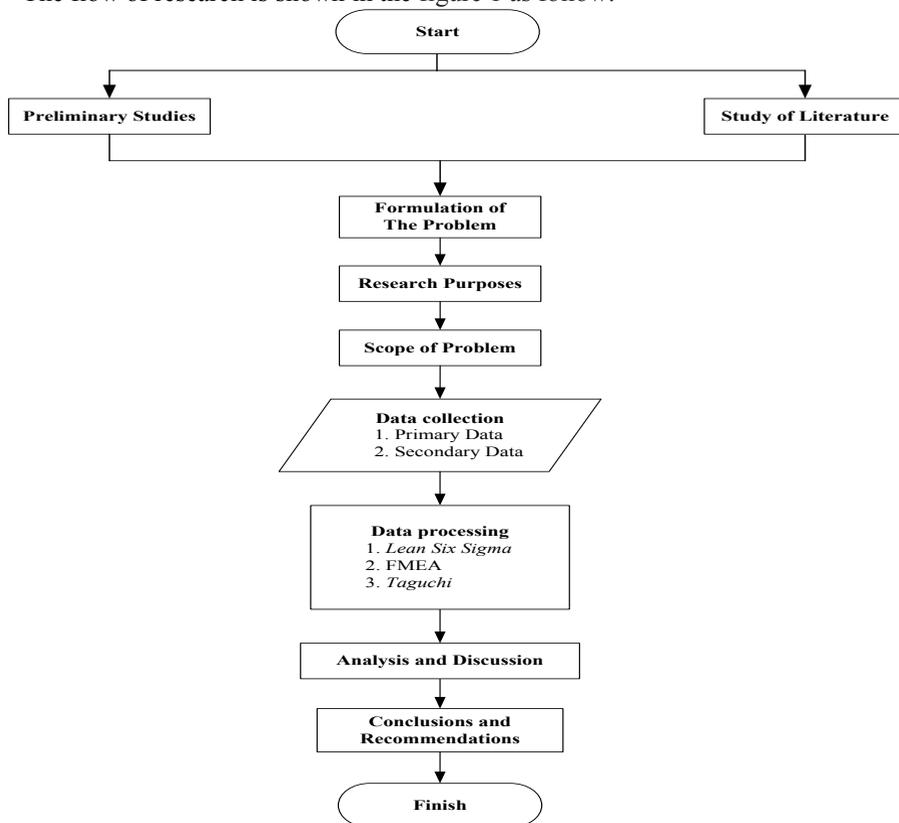


Fig.1. Flow Chart Research

4. Result And Discussion

4.1 Critical Identification of Quality

CTQ is an attribute that must be realized because it relates to customer needs and satisfaction. In SWRM 8 product there are 11 quality characteristics. The first process improvement key is to identify the main area (the main problem) and focus on the main problem. The pareto principle states that about 80% of the problems are caused by 20% of

the causes [12]. Type of defect that must be overcome based on the rules of the Pareto diagram are laps defects, underfill defects, and overfill defects.

4.2 Calculation of DPMO and Sigma Levels

The result of the Cp value is 1.514. It shows that the production process of SWRM 8 product still needs to be improved continuously till the target of 6-sigma.

4.3 Current State Value Stream Mapping SWRM 8

Current state value stream mapping of production process SWRM 8 is used to know the percentage of efficiency of production process flow of SWRM 8. The calculation of this efficiency is 61.13%.

4.4 Waste Identification

In the waste identification stage using questionnaires. Questionnaires were filled by 6 respondents, including four supervisors, one senior engineering, and one production cadre. The results obtained for the most dominant waste is waste defect, then brainstorming with one senior engineering to identify the cause of the Five why method that is currently used to identify the causes of defective product using the 5 why method. The next stage creates mapping tools using VALSAT (value stream mapping tools). Based on mapping tools, the tools used in this research is PAM (process activity mapping).

4.5 Identification of Production Process Activities

In this research, the whole time of value added activities are 59.83 minutes with a percentage of time is 61.13%. All non value added activities are 38.04 minutes with a time percentage is 38.87% and no activity is included in non value added activities. The total time is 97.87 minutes. The proposed improvement is done with the design of action based on the highest RPN value of FMEA and optimum factors of setting the roll entry guide using Taguchi method.

4.6 Taguchi Method

The following are steps of applying Taguchi method in this research:

1. The quality characteristics determination for SWRM 8 products is smaller the better so that the quality characteristics observed in SWRM 8 products are defective or not defective in SWRM 8 with the purpose to minimize the defect categories.
2. Application of orthogonal arrays. The degree of freedom in this research is 8 then the orthogonal matrix chosen is $L_9(3^4)$, which shows 3 levels, 4 factors, and 9 experiments [6].
3. Determining the number of levels and level values.

Table 1. Determining Amount And Value Factor Level

Code	Influential Factors	Level Factor		
		1	2	3
		150	200	300
A	Wear level Assembly unit	tonnages	tonnages	tonnages
B	Cooling	<1 mm	±1 mm	>1 mm
C	Lubrication	4 bar	5 bar	6 bar
D		3 ml	6 ml	9 ml

4. The Taguchi experimental results data shown that 3 replications were performed for each combination of factor level. The data can be seen in table 2.

Table 2. Taguchi Experimental Results

Control Factor				Results			Average
A	B	C	D	1	2	3	
1	1	1	1	12	12	12	12,000
1	2	2	2	10	10	10	10,000
1	3	3	3	12	12	11	11,667
2	1	2	3	12	13	12	12,333
2	2	3	1	13	11	13	12,333
2	3	1	2	13	13	13	13,000
3	1	3	2	10	11	11	10,667
3	2	1	3	12	12	12	12,000
3	3	2	1	12	12	11	11,667

Table 3. Average ANOVA

Source	SS	D _f	MS	F _{ratio}	SS'	Ratio%
A	9.185	2	4.593	15.500	8.593	34.118
B	2.074	2	1.037	3.500	1.481	5.882
C	4.963	2	2.481	8.375	4.370	17.353
D	3.630	2	1.815	6.125	3.037	12.059
Error	5.333	18	0.296	1	7.704	30.588
SSt	25.185	26			25.185	100
Mean	3721.815	1				
SStotal	3747	27				

The results obtained for optimum level combinations are A level 1 factor (level of tire wear roll entry guide 150 tonnages), C level 2 factor (cooling 5 bar), and level D factor 2 (6 ml lubrication).

The next step is calculating the confirmation experiment. Confirmation experiment results can be accepted with confidence interval because the confirmation experiment is still within the optimum yield interval. This means that the results of the taguchi experiments can be applied and the optimal level setting can be used as a reference in the production process of SWRM 8 products to reduce product defects. According to [7], decisions of optimal conditions can be accepted or not, with compare the average estimation value and the average confirmation experiment results with each trust interval.

4.7 Future State Value Stream Mapping Production SWRM 8

The following suggestions for improvement of NNVA activity include giving directions of vehicle entrance and exit reduced transport time from billet check to raw material warehouse by 3.2 minutes, cleaning magnet crane 401 from billet reduced the time of billet transfer by 1.1 minute and billet transportation from the raw material warehouse to the billet hit number checking reduced the time by 2.02 minutes, reducing the checking time of the billet hit number by positioning the billet hit number facing the pulpit so that the time is reduced by 2.6 minutes.

Based on the proposed future state value stream mapping product SWRM 8, produces stream flow production efficiency of wire rod SWRM 8 67,26%. The efficiency of the production process flow increase by 6.13 %.

5. Conclusion

The following is a conclusion obtained on the research as follow :

1. Waste in the production process of SWRM 8 in the wire rod factory of RMW Inc. are overproduction, transportation, waiting, excess process, inventory, motion and defect. Waste defect is a priority for improvement because it has the largest average value.
2. Factors that cause the dominant defect in SWRM 8 is no standard setting of roll entry guide.
3. The level of sigma capability in the production process of SWRM 8 is 4.54 with DPMO (defect per million opportunities) is 4006.55.
4. Proposed improvements to the production process of SWRM 8 in the wire rod factory of RMW Inc. are:
 - a. Reducing the billet checking time to the raw material warehouse by providing road signs and directions for vehicle directions so the time can be reduced by 3.2 minutes.
 - b. Reducing the billet loading time by cleaning the magnet crane 401 so can be decreased by 1.1 minutes.
 - c. Reducing the billet transportation time from the raw material warehouse to the billet hit number checking by clearing magnetic crane 401 so the time can be reduced by 2.02 minutes.
 - d. Reducing the checking time of the billet hit number by positioning the billet hit number facing the pulpit so can be decreased by 2.6 minutes.
5. Designed improvements to minimize the cause of potential failures on SWRM 8 products is to determine the standard setting of the roll entry guide. The optimum factors obtained include A factor with level 1 (150 tonnages of wear level), C factor with level 2 (5 bar of cooling) and D factor with level 2 (6 ml of lubrication).

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