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Integration of nominal group technique, Shainin system and DMAIC methods to reduce defective products: A case study of tire manufacturing industry in Indonesia

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A B S T R A C T

The sales of the automotive was increased by 3.6% in 2018, sparking the automotive and its spare parts industry for more opportunities. Various strategies have been made to win the competition and increase sales, to expand market share and to reduce production costs. Tire industry as automotive parts industry in Indonesia has faced with tremendous competition and the industry needs an appropriate strategy to reduce production costs by reducing defective products. The building process is workstation of the tire industry with the focus on decline on the defective products. Internal data shows the defective products in the building process of 0.20% in 2017 and 0.17% in July ~ September 2018 which were higher than the company's schedule of 0.12% of total production. The NGT, Shainin system and DMAIC (Six sigma) methods are expected to improve defective products of building process. Based on Pareto diagrams it is clear that there were six defective products causing high defective products. However, with the limited research, BLP defective products with the highest defective product (48%) was used as a pilot project in this study. The preliminary results indicate that the proposed method of this paper could succeed in improving the baseline performance of the building process (sigma level) from 4.48 to 5.02 sigma and could reduce the cost from IDR.1.427.500.00 to IDR. 161.000.000 or 88.69%.

1. Introduction

The world automotive industry especially personal car makers have shown positive growth since 2018 (www.jato.com), an automotive research institute in the United Kingdom stated that sales of 44 million units up 3.6% compared with the previous year. This fact encourages business people, especially the automotive and spare parts industry to look for better ways for competitive market. The conditions divert in increasingly fierce competition to get each other's opportunities. One of the auto parts industries in Indonesia is tire industry involved into some significant competition and needs to apply various strategies to achieve optimal benefits of increase in sales. One strategy is to reduce production costs by eliminating all waste in the process by reducing defective products to help reduce the production costs.

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The decline in building process defect products is the focus of this research. The building process is one of the production processes in the tire industry, which is associated with a process of combining all tire assembly materials (inner liner, ply, bead, rain forced, sidewall, belt, cover and tread) into a product. In the building process; there are two main stages, the main stage is related to the first building stage which produces a product called green case and the next main stage is the second building that continues the first building process for the process to become the final output of the building process; namely green tire. From the company's internal data, building process defective products in 2017 was 0.20% it was reduced to 0.17% of the total production in July ~ September 2018. In this case, the building process defective product is higher from the schedule determined by the company, which is 0.12%. The study aims to get the cause of the defective product and identifies the financial loss caused by the defective product. In this study, the integration of Nominal group technique (NGT), Shainin system and DMAIC (Six sigma) are used for analyzing defective products and the FMEA method is an option in implementing corrective action in the hope that the process of building a defective product can be properly controlled by the company's schedule.

2. Literature review

Quality is an important issue in the highly competitive business world (Raman & Basavaraj, 2018). Quality even is the key for the consumer's decision to decide on the products and services offered by the producers. Quality must satisfy customer (Khawale et al., 2017) and generally it can be interpreted as the whole characteristics of the product in order to meet the customer's expectations (Suwendra, 2014). Any organization is required to understand the customers' needs, with various research and development for later design and it is a product that has superior characteristics, so product quality is always associated with customer's expectations (Hadi, et al., 2017; Khawale et al., 2017; Chakrabarty & Tan, 2006). Understanding the quality should be a major consideration in designing and manufacturing products (Raman and Basavaraj, 2018). Continuous Quality Improvement is also a producer's sides (Pyzdek, 2003), so getting the best quality at all times is an effort to improve the competitiveness of the company (Adeyemi & Needy, 2006) and will have a big impact on consumer loyalty (Tannady, 2015) so to reach a good quality, the required quality control system is appropriate and according to company's needs (Bauer, et al., 2006). Quality control is a series of activities carried out in an effort to maintain the value of the product against dimensions that are quality characteristics before the product is distributed to customers (Venkateswaran & Padmanaban, 2018). Quality control activities can generally be interpreted as measurements by comparing products to some standards (Bauer, et al., 2006; Juran & Godfrey, 1998). Many methods can be used in quality control and one of them is called Six Sigma.

Six sigma is one of the methods for improvement and quality control implemented by many companies or organizations. The concept of six sigma is to emphasize on the principle of 3.4 defective per one million products proven to increase the competitiveness of companies or organization (Raman & Basavaraj, 2018; Adeyemi & Needy, 2006; Gerger & Firuzan, 2016). Six sigma as management philosophy means that the organization or company wishes to increase the benefit by improving the quality of the process (Flifel et al., 2017). The six sigma method proved to be very flexible and can be applied almost entirely from all industries, both of large and small industries and all sectors such as: Manufacturing industry (Hung, et al., 2011; Desai, 2013; More and Pawar, 2011; Riddick, et al., 2016). Health and laboratory services, Home industry sector, Construction sector (Karakhan, 2017), etc. Six Sigma is a comprehensive mix of all tools and techniques of quality improvement and productivity, such as Total Quality Management (TQM), COPQ, ISO 9000 series, Lean Management, Theory of Constraints, Balance score card, SWOT analysis and KPI (Desai, 2013; Gajbhiye, et al., 2016). The existence of a systematic solution framework of DMAIC is the advantage of six sigma methods compared with other methods (Desai, 2013). Six-sigma performance focuses on reducing process variation to reduce defective products (Chang & Wang, 2007). Reducing variations and defective products can lead to increase the profitability and increase customer satisfaction (Croft & Kovach, 2012; Gandhi, et al., 2019; Syafwiratama, et al., 2017; Hussain et al., 2014; Elbireer et al., 2011). Reduction of defective products can be accomplished by detection and measurement as well as the steps of systematic process performance improvement that lead to the transformation of fundamental organizational culture (Raisinghani, et al., 2005).

Nominal group technique (NGT) is an evaluative, qualitative and quantitative methodology that allows generating ideas and thoughts from group discussion participants, by asking a question, while maintaining anonymity of ideas (Lennon et al., 2011). The NGT process requires the involvement of direct and non-hierarchical participants, thereby ensuring a democratic and respectful experience of the participants (Potter et al., 2004). The advantages of NGT compared with other focus group discussions are that in NGT there is a stage of voting of idea which is the stage of appraisal or weighting of ideas that has been obtained from generating idea stage so that the output of NGT is a quantitative value to facilitate the decision-making the end of the NGT process. The idea of obtaining the highest value is chosen as the main priority and then the sequence of priority is according to the scoring (Pena, et al., 2011).

The Shainin system is a practical method of problem solving for the current industry that operates on mass production, operating at high speed and very large quantities and operates 24 hours a day. The Shainin system is effective for use in manufacturing to determine the root of the problems. The unique stages within Shainin system are an easy and inexpensive technique in determining the dominant factor in a problem known as Generating Clue. By multiplying observations, investigations and comparison the clues of obtained so that existing factors can cure the dominant factor of the problems encountered. The Generating Clue process is performed from micro scale to macro scale by comparing best of the best group (BOB) with Worst of the worst (WOW) group (Kadam et al., 2018). The first stage is to determine the root of the problem or the main factor (referred to as Red X) which starts with Generating Clue, specifying the variables that are supposed to relate to the existing problem, doing the test so that the root cause factor of the problem is confirmed correctly. While the second stage is to determine the action on the root of the problem, the implementation and monitoring of the results. Shainin system is combined with manufacturing facilities that can perform traceability with Information of Technology which makes it possible to use process database in observation, investigation and comparison easily and quickly without having to perform experimental factor screening (Steiner et al., 2008) By doing many observations it will be better and faster in determining the dominant factor and problem solving process as a whole.

T-test is a statistical method used to test the hypotheses so that the difference between the two conditions is known, namely the condition of the actions taken against the previous reference or condition. The t-test is used to test the differences between two different conditions that have interval/ratio data (Siregar, 2015). Hypothesis testing involves two contradictory conditions, namely H_0 which states that there is no significant differences between the two conditions and H_1 which states there is a significant differences between the two conditions tested (Locati, et al., 2016). The decision to accept or reject H_0 or H_1 is determined by the value of the t- test calculated against t-table where the provisions apply (Siregar, 2015; Darmayani et al., 2017) as follows:

If t-count < from t-table then H_0 is accepted and rejects H_1.

If t-count > from t-table then H_1 is accepted and rejects H_0.

Hypothesis acceptances decisions are seen from the comparison of the p value to the α value where the opposite provisions apply from the value of t-count (Naito et al., 2017) are:

If p value < of α value then H_1 is accepted and rejects H_0.
If p value > of α value then H_0 is accepted and rejects H_1.

Failure mode and effects analysis (FMEA) is one of the techniques for assessing the effects of potential failure of the system (Shariati, 2014). FMEA is a systematic approach for analysis, definition, budget, and risk assessment that includes identifying and analyzing: (1) all failure modes of various parts of the system, (2) effects of the failure mode on the system (3) how to avoid failure and or moderate the effects of a failed system (Putra & Purba, 2018). FMEA has a measurement method that is reviewed from three perspectives are: Severity (S), Occurrence (O), Detection (D) (Chin et al., 2008). The evaluation system in FMEA gives a number between 1 and 10 where 1 is the best value and 10 is the worst value for each of the three perspectives. By multiplying the value for severity (S) occurrence (O) and detection (D) the decision-making team calculates the risk priority number (RPN), RPN = S × O × D, provided that a higher RPN value is considered more important and will be given a higher priority for correction. Not all RPN values should be corrected, but seeing the critical value will be known to which RPN should be corrective action if any critical RPN determination is as follows CRITICAL RPN = ∑RPN / ∑ Risk (Suryani, 2018). RPN helps decision-making teams detect parts or processes, which require priority actions for appropriate improvement, but the final decision depends entirely on company policy (Shariati, 2014).

3. Research methodology

The design of this study is a comparative study of previously occurring data called "Ex post Facto Research", Ex post facto is a research conducted after a problem occurs which aims to find the possible causes of change of behavior, symptoms or phenomena in events that have happened. This study aims to find out the factors that cause defective product in the building process in a tire industry. The six-sigma method with DMAIC (Define, Measure, Analyze, Improve and Control) will be used in this study with NGT and Shainin system integrates, with the following research framework:

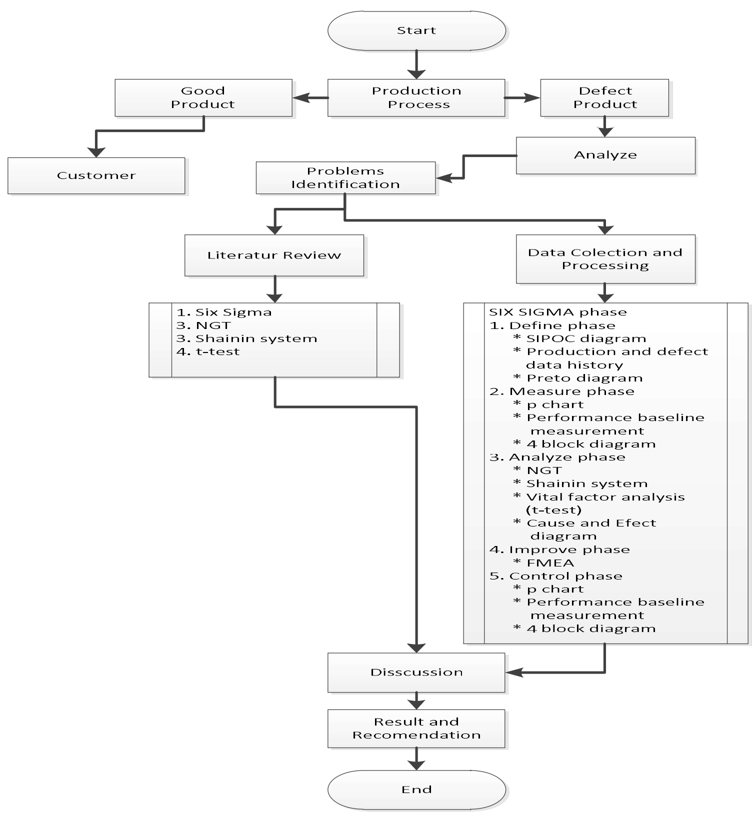

Fig. 1. Research framework

Based on research frame work as in Fig. 1., with the integration of NGT, Shainin system and DMAIC (six sigma) methods, with tools of statistics such as p charts, pareto diagrams, performance baseline measurements, vital factor analysis (t-test), four blocks diagram and FMEA method is expected to identify, analyze and improve defective products building processes can be derived according to the schedule charged by the company and get savings to maintain the sustainability of the company.

4. Results and discussion

In the production process of the building data there are still defective products that are higher from the set schedule. According to production report of year 2017, the number of productions was 12.420.581 pcs, the number of defects was 24.304 pcs or 0.20%, and the current condition of the building process with the production of 3.510.530 pcs was defective products of 5.912 pcs 0.17%. While the company's schedule was only 0.12% of the total production. This study aims to analyze and carry out effective actions to reduce defective products and also analyze financial losses with integrating NGT, Shainin system and DMAIC (six sigma) methods with the following steps:

4.1. Define phase

In the define phase there are 2 activities, are:

4.1.1. SIPOC diagram arrangement

The Supplier Input Process Output Customer (SIPOC) diagram aims to map the production process and in the step / process, the causes of defective products can be identified, while the SIPOC building process diagram is as follows:

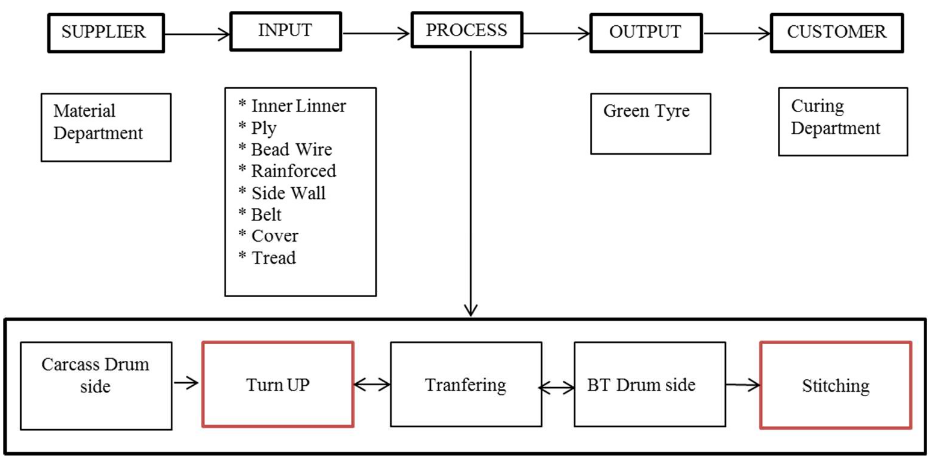

Fig. 2. SIPOC diagram of building process

Fig. 2. explains that building process suppliers are materials department that produce material as input to the building process; namely: Inner liner is the innermost tire layer, ply is a tire frame, bead wire is a wire circle as a measure of the tire ring, reinforced is a bead reinforcement material, sidewall is a retaining material beside of tire, belt, cover and tread are combined material that functions as a protective bottom side of the tire. The building process is carried out from two sides; namely: carcass drum side, where there it is an assembly process of material Inner liner, ply, reinforced and side wall, in the side of the carcass drum where there is a turn up process which is the process of inserting bead wire into materials that has been assembled before. Then on the BT drum side there is an assembling belt, cover and trend process. The transferring moves to take BT drum assembling material to be combined with assembled material on carcass drum for stitching to become the final product of building process which is Green tire. Then green tire is sent to the curing process as a building process customer. The process of turn up and stitching is a process that is the focus of this research in an effort to reduce defective products that occur in addition to other processes.

4.1.2. CTQ Determination

Pareto diagram of building process defects can help in determining CTQ, while the Pareto diagram in question are:

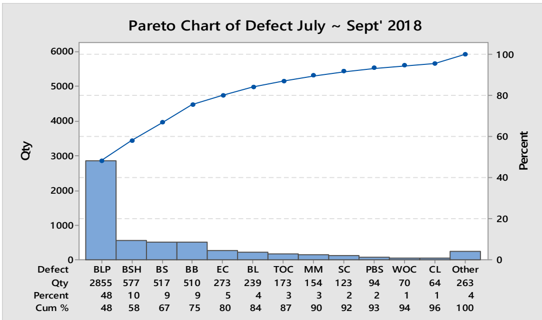

Fig. 3. Types of building process defective products

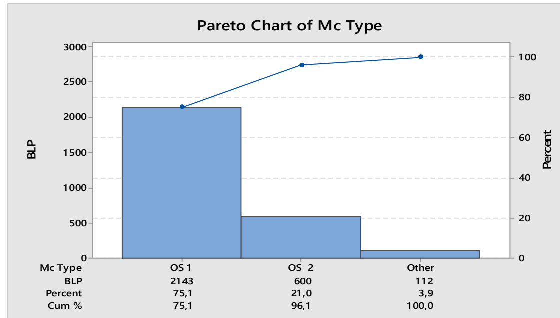

Fig. 4. BLP based on machines type

Fig. 3 explains that BLP (Blown Ply) defective products are the largest number of contributors to defective product building processes as a whole. In this research BLP defective product became a pilot project from the decline of defective products of building process. From the BLP data which is the highest defective product (48%) we can further breakdown to simplify analysis, however the breakdown of BLP defective product data is shown in Fig. 4, which states that the CTQ of BLP defective product consists of 2 types; namely the BLP defective product in OS 1 and OS 2 process.

4.2. Measure phase

Measure phase is the measurement process to find out the current condition, which is a condition before improvement, in this phase we have used p chart, baseline performance measurement (sigma level), four block diagram and COPQ analysis. In the performance baseline measurement of the three-month in building process (July ~ September 2018) sigma level is as follows:

Table 1
Performance baseline (sigma level) of building process July ~ September 2018

Month	Production	BLP	CTQ	DPU	DPO	DPMO	YRT	YNA	Zlt	Zst
July, 2018	178974	884	2	0,0049	0,0025	2469,63	0,9951	0,9975	2,8114	4,31
August, 2018	197420	346	2	0,0018	0,0009	876,30	0,9982	0,9991	3,1294	4,63
September, 2018	139473	280	2	0,0020	0,0010	1003,78	0,9980	0,9990	3,0893	4,59
Average	515867	1510	2	0,0029	0,0015	1463,56	0,9971	0,9985	2,9755	4,48

Table 1 indicates that sigma level (Zst) month of July ~ September 2018 is 4.48 sigma. Further mapping into four block diagrams shows the ongoing process capability (Z). By calculating Zshif and Z bench. It can be mapped four block diagrams are as follows:

$$
\begin{aligned}
\text{Zst} &= \text{Zbench.lt} + 1{,}5 \\
4{,}48 &= \text{Zbench.lt} + 1{,}5 \\
\text{Z bench.lt} &= 4{,}48 - 1{,}5 \\
\text{Z bench.lt} &= 2{,}98 \\
\text{Zshift} &= \text{Zbench.st} - \text{Zbench.lt} \\
&= 4{,}48 - 2{,}98 \\
&= 1{,}50
\end{aligned}
$$

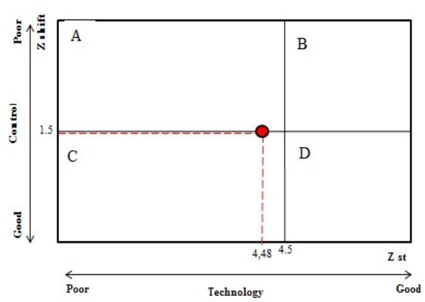

Fig. 5. Four block diagrams of sigma level of current condition

Based on the four block diagrams in Fig. 5, it is known that current performance baseline in quadrant C from control side is good and still lacking in technological side, which means we need some systematic improvements so that both sides are expected to be in proper control and proper technology category. COPQ analysis in this study represents the conversion of the number of defective products into financial units, which is the potential loss analysis that the company has to bear due to defective products, based on the company's internal data that the costs of the tire defective product is IDR. 500.000/pcs, so the current loss of the company are: 2855 pcs × IDR. 500.000 = IDR. 1.427.500.000.

4.3. Analyze phase

Analyze phase is the third phase of the DMAIC cycle, which is the analytical from the measure phase and in this phase it is conducted by NGT (nominal group technique) and Shainin system to obtain information about the potential cause (vital factor) of the defective products (BLP), and then perform a vital factor analysis using the t-test to find out a dominant cause of the defective product (BLP).

4.3.1. Nominal group technique (NGT)

NGT is a method to get the cause of a problem by generating of idea from the expert person and each of them gives assessment to those ideas, in this process, the NGT process involves six members with the following results:

Table 2
Result NGT Cause of BLP defective product

No	Cause	Assessment						Value
		ADH Production	SPV Production	Operator Set up	SPV Engineering	Technician	SPV Inspection	
1	Brush roll high uneven	3	9	3	9	9	9	**42**
2	Bubble between TUH and wingtip	9	3	3	9	9	3	**36**
3	Life time bladder over	3	3	3	9	1	3	22
4	Pressure turn up under	3	9	3	3	3	3	24
5	Push can distance under	9	9	3	3	1	3	28
6	Pricking BEC not translucent	9	9	9	3	3	3	**36**
7	Turn up wrinkled	9	9	1	3	9	9	**40**
8	New Operator	1	3	1	9	3	3	20
9	Shift of work	1	1	3	3	1	3	12
10	Temperature and humidity room over standard	1	1	1	3	9	9	25

After the value of each potential cause of the defective product is known as in Table 2, then determining the potential cause of the defective product can be determined as follows:

NGT ≥ (Total potential x Total number of evaluators) / 2 + 1
NGT ≥ (10 × 6) / 2 + 1
NGT ≥ 31

From Table 2 it can be interpreted that out of ten potential causes of the defect that existed, there are three causes with values of higher than 31, that became the vital factor of the BLP defective product, namely: brush roll high uneven, bubble between TUH and wingtip, pricking BEC not translucent and turn up wrinkled.

4.3.2. Shainin system method

Shainin system is a method that begins from generating clues of problem definition by performing various comparations from the worst of the worst group (WOW) with the best of the best group (BOB), in this study comparations include process parameters, product parameters and design parameters each using 30 data from each group, with the goal of obtaining possible potential causes (red X) BLP defective product (green Y) by using t-test with conditions:

if p value > α value, H0 is accepted, that is not a vital factor.
if p value < α value, H1 is accepted, that is a vital factor.

The results of the shainin system comparison with the use of the t-test in the calculation of the determination of vital factors causing the BLP defective product are:

Table 3
Vital factor of cause BLP defective product by Shainin system method

No	Cause factor	Potential cause	p value	α	Judgment
1	Parameter of process	Bead to bead distance	0.515	0.05	Not vital factor
2		Turn up distance	0.469	0.05	Not vital factor
3		Pre shape distance	0.103	0.05	Not vital factor
4		Final shape distance	0.032	0.05	Vital factor
5		Radial Stitching distance	0.000	0.05	Vital factor
6	Parameter of product	GTH vs. Spacer	0.587	0.05	Not vital factor
7		PDW variance	0.660	0.05	Not vital factor
8		BEC variance	0.539	0.05	Not vital factor
9	Parameter of design	Belt 1 distance to BEC	0.703	0.05	Not vital factor
10		Sidewall code	0.696	0.05	Not vital factor
11		Ply code	0.696	0.05	Not vital factor
12		Belt code	0.660	0.05	Not vital factor
13		Series variance	0.468	0.05	Not vital factor

From the results of NGT (Table 2) and Shainin system (Table 3), there is a vital factor causing the BLP defective product, which are: brushroll high uneven, bubble between TUH and wingtip, turn up wrigkled, final shape is less touch, pricking BEC not translucent, and radial stitching distance less. After we have determined the vital factor of BLP (OS 1 and OS 2) defective product, the next step is the CED (cause effect diagram) analysis to determine the root of the problem, as for CED analysis as follows:

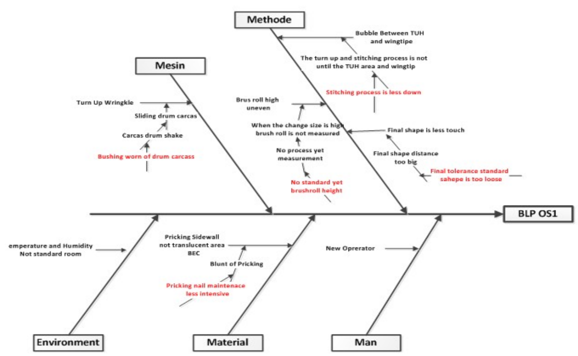

Fig. 6. Cause effect diagram of BLP OS1

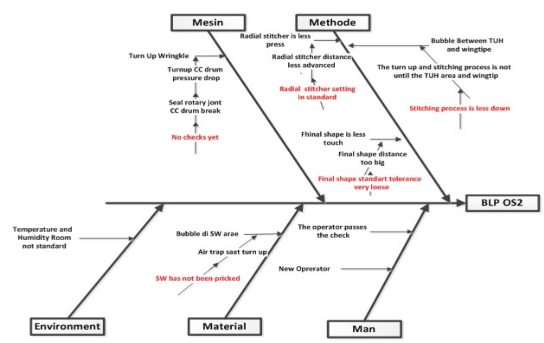

Fig. 7. Cause effect diagram of BLP OS2

Based on the CED as in Fig, 6 and Fig. 7. It can be seen root causes of BLP defect (OS1 and OS 2) are:

1. Method : Stitching process is less down, final shape standard very loose, setting radial stitching already standard (if there are defect), no standard brush roll high.
2. Machines : No check seal rotary joint, bushing worn of carcass drum.
3. Materials : Sidewall had not pricked, pricking nail maintenance less intensive.
4. Man : The operator passes of check
5. Environment : Temperature and humidity room of standard.

4.4. Improve phase

The improve phase is the fourth stage in the six sigma method, which is the corrective action step for the causes of the problem (root of problem) that has been obtained in the analyze phase. In this study, the improve phase is used by the FMEA (failure mode effect analysis), by looking at the value of the RPN sequentially from the highest to the lowest which will be the order of improvement. The FMEA in this study are:

Table 4
Calculation of FMEA BLP defective products

Factor	Potential failure	Potential causes of failure	S	O	D	RPN	Proposed corrective action
Method	Radial stitching is less press	Standard radial stitching is not fixed	6	6	8	228	Revision of standard radial stitching
	Bubble between TUH and wing-tip	Stitching process is less down	8	6	8	384	Change method traverse stitching
	Final shape distance is less touch	Final shape distance standard very loose	6	6	8	288	Revision of standard final shape distance
	Brush roll high uneven	No standard brush roll high	6	4	8	192	Make standard brush roll high
Machine	Turn up wrinkled	No check seal rotary joint	6	4	8	192	Change seal and insert to PM item
	Turn up wrinkled	Bushing worn of Carcass drum	8	2	8	128	Change Bushing
Material	Bubble in SW area	SW not pricking	8	4	6	192	Revision spec pricking
	Pricking BEC not translucent	Pricking nail maintenance not intensive	6	4	8	192	Maintenance pricking from 1 to 2 times perweek
Man	New operator	Operator passes check	4	2	8	64	-
Environment	Temperature & Humidity NG	Control detector failure	3	2	8	48	-

After the RPN, value has been obtained to determine the potential of any causes that should be corrected is to determine the Critical RPN, by means of:

$$\text{CRITICAL RPN} = \Sigma \text{RPN} / \Sigma \text{ Risk}$$
$$= 1098/10$$
$$= 109.8$$
$$\text{CRITICAL RPN} = 110$$

Based on RPN value in Table 4, there are seven potential failures that must be fixed. That is by implementing the proposed improvement as in Table 4 above.

4.5. Control phase

The control phase is the last step in the six-sigma method where the control phase is carried out by process control activities after improvement. P chart, performance baseline (sigma level) and four-block diagram are done again to find out the level of success of the implementation of improvement. In this study, the control stage was carried out by taking production data and defective products in January ~ March 2019, with the following data:

Table 5
Performance baseline (sigma level) of building process January ~ March 2019

Month	Production	BLP	CTQ	DPU	DPO	DPMO	YRT	YNA	Zlt	Zst
January, 2019	256381	117	2	0.0005	0.0002	228.18	0.9995	0.9998	3.51	5.01
February, 2019	245147	114	2	0.0005	0.0002	232.51	0.9995	0.9998	3.50	5.00
March, 2019	239430	92	2	0.0004	0.0002	192.12	0.9996	0.9998	3.55	5.05
Average	740958	323	2	0.0004	0.0002	217.96	0.9996	0.9998	3.52	5.02

Table 5 shows the sigma level (Zst) month of January ~ March 2019 is 5.02 sigma. With the same calculation as in the measure phase, it can be arranged in four block diagrams (after improve condition) as follows:

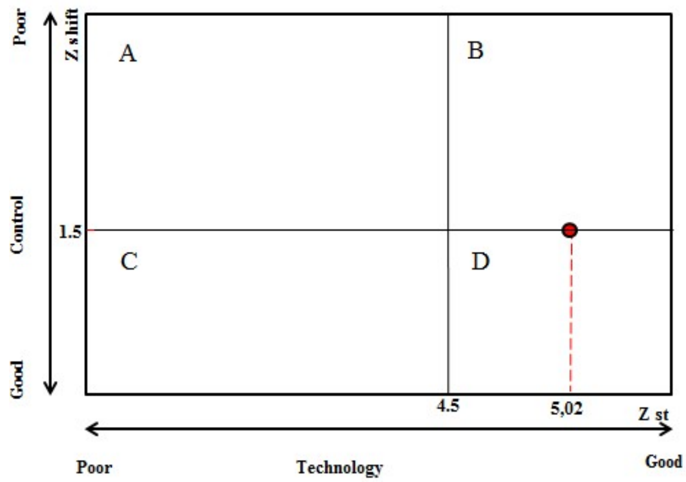

Fig. 8. Four Block diagrams of sigma level after improve condition

Looking at the four block diagrams at Fig. 8 we can learn the sigma level after the improvement of the condition is located on quadrant D, which means proper control and proper technology conditions, which look good control and technology side of leading to the 6 sigma concept by performing advanced analysis of other defective products very likely can be performed. COPQ analysis after improvements based on production and QC report at January ~ March 2019 stated that the number of defective products of 323 pcs when converted into financial unit would be: 323 pcs × IDR 500.000 = IDR.161.000.000, and decreased 88.69%. The fact of positive trend in decreasing BLP defective products by using the integration of the NGT method, Shainin system and DMAIC (six sigma), as proposed by findings of this study are used as a new standard of building process to prevent similar problems from re-emerging in the future.

5. Conclusion

Based on the findings in the define, measure, analyze and implement improvements in the improve phase and monitoring the improved results in the control phase, it can be concluded that the integration of NGT, Shainin system and DMAIC (six sigma) with the pilot project reduction of BLP defective product could improve the performance baseline (sigma level) from 4.48 to 5.02 sigma. In addition, the four block diagram showed conditions before improvement were on quadrant C while after improvement conditions were upgraded to quadrant D and this research succeeded to reduce cost due to defective product from IDR. 1.427.500.000. to IDR. 161.000.000., which means 88.69% decreased. We hope the results of this research can be applied to defective product of the other building process and it can be used for the improvement of the conditions of defective products of building process.

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