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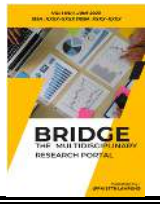

Analysis of Cotton Yarn Product Defects in the Production Process of the Cotton Department Using the DMAIC Six Sigma Approach

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ABSTRACT

The smoothness of the production process is an indicator of success in increasing the effectiveness of a manufacturing industrial company. In the product manufacturing process, several types of *defects occur* , such as dirty thread, uneven thread rolls, tangled threads or non-standard loose thread rolls and others. This research focuses on finding types, *defect factors* , sigma values and RPN at PT. Indorama *Teknologies Complex* uses the DMAIC and FMEA Phase approach methods . In this research, researchers collected data by means of observation and interviews. Observations were carried out by direct observation at the research site taking place at PT . Indorama Teknologies *Complex* . Interviews were conducted with a question-and-answer session regarding the possible causes of product *defects* with production operators and supervisors in the field .

The average sigma value of the yarn production process *cotton* is 4.19 sigma. because there was a value that exceeded the control limit, a revision was carried out which made the sigma value increase to 4.22. The sigma value is still at level 4. Based on the 5W+1H analysis, the proposed improvement is strict supervision so that maintenance on the machine is carried out according to the schedule set by the company on a regular basis .

Keywords: *Defect , Six sigma, DMAIC, FMEA*

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INTRODUCTION

At this time, the development of industrial technology in Indonesia means that companies are inevitably required to work quickly but must produce quality products. Product quality is also an important indicator for companies to be able to continue to survive amidst the intense competition in today's industrial world. One of the developments in product quality can be seen from company income data. Quality control is one of the factors that can determine the success or failure of a company, good or bad products are identified by control activities that lead to improving the quality of the products produced.

There is a need to handle product quality control and make improvements to improve product quality in a company by using statistical product quality control methods. *(Febria Suci et al., 2017)* . PT. Indorama *Teknologies Complex* is part of PT. Indorama Synthetics Tbk. The result of the production is producing cotton-based materials into yarn. Many factors can influence product results in a company. One of them is the presence *of defects* during the production process. To meet consumer demand and satisfaction, the company always strives to increase its production to the best quality. However, in the process of making this product, several types of *defects occur* , such as dirty thread, uneven thread rolls, tangled threads or non-standard loose thread rolls and others.

Figure 1. Graph of the Number of Defects in Cotton Yarn Products

The number of defects can cause production in the company to decrease so that the company's productivity is reduced, which results in the company not only experiencing material losses but also the image that has existed for a long time in the

company will become less good in the eyes of consumers because of their lack of satisfaction with the product. There are defective products that exceed the tolerance limits at PT. Indorama Teknologies *Complex* causes products to be unable to compete with similar companies with cheap selling prices and better quality for the same type of product.

This research was also carried out to help companies find the causes of product defects in the production process every month, in the *cotton department* at PT. Indorama Teknologies *Complex* .

The author conducted research using the DMAIC approach, the six sigma method by applying the improvement and quality improvement method according to (Ulva, 2018) , namely *the Define* , *Measure* , *Analyze* , *Improve* and *Control* (DMAIC) phase stages.

METHODS

The variable used in this research is to look for the types and causes of the largest *defect factors* in the yarn production process through analysis of the DMAIC stage method at PT. Indorama Teknologies *Complex* . In this research, the researcher collected data by means of observation which was carried out by direct observation at the research site to observe the progress of the process. ongoing cotton yarn production at PT . Indorama Teknologies *Complex* and interviews conducted with question and answer sessions regarding the possible causes of *defects* in products to production operators and supervisors in the field .

Six Sigma

According to Gaspersz, the method used in this research is the six sigma method which is a method of quality control and improvement implemented by Motorola since 1986. Six sigma is a form of quality improvement towards the target of 3.4 *Defects Per Million Opportunities* (DPMO) for each products, both goods and services, in an effort to reduce the number of defects. According to Evans, six sigma can also be defined as a method of improving business processes which aims to find and reduce factors that cause defects, reduce cycle time and production costs, increase productivity, meet customer needs, achieve optimal machine utility and get better results. in terms of production and service. (Surga Ridwani, 2018).

Table 1. Sigma Quality Level

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Yield (Probability without disabled)	DPMO (*Defect Per Million Opportunities*)	Sigma (σ)
30.9%	690,000	1
69.2%	308,000	2
93.3%	66,800	3
99.4%	6,210	4
99.98%	320	5
99.999%	3,4	6

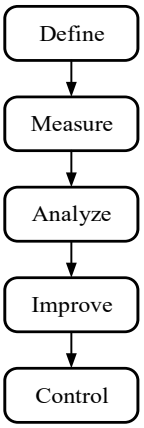
Source: Hendradi (2006:4) in (Ulva, 2018)

Six Sigma applications focus on defects and variations starting with identifying critical elements to the quality of a process.

Six Sigma with DMAIC Stages (*Define, Measure, Analyze, Improve, Control*)

DMAIC is carried out systematically based on science and facts (*systematic, scientific, and fact based*). The following are the stages in the DMAIC cycle and the steps that must be implemented at each stage (Panjaitan, 2017).

Table 2. Stages of DMAIC



a. *Define* Stage

Define stage is the first stage of the DMAIC process, this stage aims to bring together the opinions of the team and sponsor regarding the project to be carried out, including the scope, objectives, costs and targets of the project to be carried out .

b. *Measure* Stage

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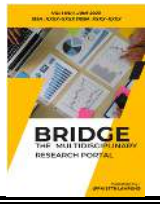

The Measure phase is a phase for measuring the level of defects in a production. Measure is a logical follow-up to the define step and is a bridge to the next step.

The steps taken at this stage are (Ulva, 2018) Determining Critical To Quality (CTQ), Knowing the order of *Critical To Quality (CTQ), Measuring the stability of the Performance Baseline process (Performa Baseline) is usually determined using a DPMO (Defect Per Million Opportunity*) measurement and sigma value.

DPMO is interpreted as in a single product unit, the average chance of failure of a CTQ characteristic is only 3.4 failures per one million opportunities. The formula for calculating DPMO.

$$DPMO = \frac{(Jumlah\ produk\ cacat\ )}{(Banyak\ produk\ cacat\ \times CTQ\ potensial)}\ X\ 1.000.000$$

c. *Analyze* Stage

The steps taken at this stage are the cause of *the defect* (technically), namely knowing the technical cause of *the defect* in a process and tracing the root cause of the problem, namely carrying out an analysis of the root cause of the problem which can be done using *a cause and effect diagram* by looking at 5 factors. namely humans, methods, machines, materials and the environment.

Tools used in the *Analyze stage* :

1. *Fishbone* Diagram
2. *Control* map p
3. *Failure Modes and Effects Analysis* (FMEA)

d. *Improve* Stage

In this step, an action plan is implemented to implement six sigma quality improvements. After the sources and root causes of quality problems are identified, it is necessary to determine an action plan to improve six sigma quality.

e. *Control* Stage

According to Gaspersz, this is the final operational stage in efforts to improve quality based on six sigma. At this stage the results of quality improvement are documented and disseminated, successful best practices in process improvement are standardized and disseminated, procedures are

documented and used as standard guidelines, and ownership or responsibility is transferred from the team to the owner or person in charge of the process.

RESULTS AND DISCUSSION

Data collection

Table 3. Data on the Number of *Cotton* Yarn Product Defects

Dept	Type of Defect	Number of Defects (kg)			Total (kg)
		February	March	April	
Cotton Units	Dirty Yarn	3083	2703	3488	9274
	Uneven Roll	6575	7066	6560	20201
	Tangled thread	107	192	262	561
	Roll of loose thread	235	36	36	307

Source: PT. Indorama Teknologies *Complex*

Define

Identify quality standards issues

The following are the four most common causes that occur in the production process *cotton* thread identified include :

a. Dirty Yarn

This type of defect, where there are stains on the finished yarn product, can be caused by oil spilling on the machine or production area & can occur because the operator's hands are not clean when picking up the yarn.

b. Uneven Rolls

A type of defect where the thread winding is not neat and the thickness is thin which results in uneven thread.

c. Tangled thread

Defects that occur due to blockages that cause the thread to become tangled.

d. Roll of loose thread

A type of defect where the roll has a hardness outside the normal limit which does not meet the standards, thus affecting the weight of the roll and hampering further processing.

Identify action plans that must be carried out based on the results of observations:

a. Carrying out repairs to machines that are less than optimal in production and adjusting machines according to SOP .
b. Increasing the workforce in carrying out work and providing motivation to the workforce .
c. Increased supervision of workers when carrying out work .

Setting six sigma quality improvement goals and objectives

Based on the results of observations made to reduce or suppress defective products from the highest of 67% and the lowest of 1% based on known percentages, it is hoped that this will be able to suppress or reduce the level of defects. With the four defects, namely dirty thread, uneven spools, tangled threads and loose thread spools, based on the problem of defective products which can cause losses to the company, the company needs to carry out strategic planning in its operations with appropriate planning and corrective action.

Measure

The Measure phase is a phase for measuring the level of defects in a production.

a. Determining *Critical To Quality* (CTQ)

In determining the type of *defect in the cotton* yarn production process (short fibers, twig contamination, tangled threads, soil contamination) which will be the focus of this research regarding the *critical to quality* (CTQ) sequence.

Table 4. *Critical To Quality* (CTQ) Type of Defect in *Cotton* Yarn Production Process

No	Type of defect	Number of defects (Kg)	Cumulative	% disabled	cumulative %
1	Uneven Winding of Thread	20201	20201	67%	67%
2	Dirty Yarn	9274	29475	31%	97%
3	Tangled thread	561	30036	2%	99%
4	Roll of loose thread	307	30343	1%	100%

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Amount	30343	30343		

Source: Data processed 2023

Pareto Chart

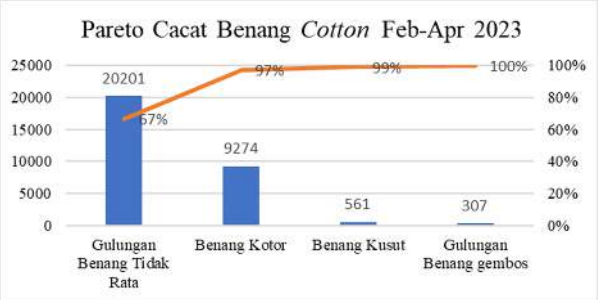


Figure 2. Pareto Diagram Types of Defects in the *Cotton Yarn Production Process*

Pareto diagram above, the most dominant type of defect in the *cotton yarn production process* is tangled yarn with a percentage level of 67%.

Pareto diagram was created to determine the importance or priority of the categories of causes to be analyzed so that the level of defects in the *cotton yarn production process can be determined* in graphical form.

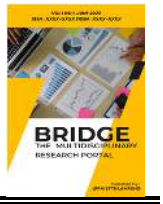
Calculating *Defect Per Opportunities* (DPO) And *Defects Per Million of Opportunities* (DPMO)

Table 5. DPO and DPMO also Sigma Value of *Cotton Yarn*

No	Date		Total Produksi (Kg)	Gulungan Tidak rata	Proporsi	Banyak CTQ	DPO	DPMO	Nilai Sigma
1	Feb	Ke - 1	108536	1260	0,0116	4	0,002902	2902	4,25
2		Ke - 2	108016	2289	0,0212	4	0,005298	5298	4,05
3		Ke - 3	106346	1150	0,0108	4	0,002703	2703	4,28
4		Ke - 4	151815	1876	0,0124	4	0,003089	3089	4,23
5	Mar	Ke - 1	106476	1537	0,0144	4	0,003609	3609	4,18
6		Ke - 2	107398	2594	0,0242	4	0,006038	6038	4,01
7		Ke - 3	106878	1376	0,0129	4	0,003219	3219	4,22
8		Ke - 4	154416	1559	0,0101	4	0,002524	2524	4,3
9	Apr	Ke - 1	107847	1485	0,0138	4	0,003442	3442	4,2
10		Ke - 2	104070	1522	0,0146	4	0,003656	3656	4,18
11		Ke - 3	105444	1455	0,0138	4	0,003450	3450	4,2
12		Ke - 4	133010	2098	0,0158	4	0,003943	3943	4,15
Jumlah			1400252	20201	0,0144	4	0,003607	3607	4,19

Source: Data processed 2023

The sigma value for Uneven Rolls is 4.19 with a *Defect Per Million Opportunity* (DPMO) value of 3607. Calculating *Defect Per Opportunities* (DPO) is a measure of



failure that shows the number of defects per opportunity. The following is a formula and example of DPO calculation for February 1st week 2023, as follows:

$$DPO = \frac{Defect}{Produksi \times Kriteria\ CTQ}$$

$$DPO = \frac{1260}{108536 \times 4} = 0{,}002902$$

Then calculate the DPMO value:

$$DPMO = \left(\frac{D}{U\ x\ O}\right)\ x\ 1.000.000$$

Information :

D = Number of defects

U = Number of production units

O = Number of defects (*opportunity*) / CTQ

So :

For DPMO February 1st week

$$DPMO = \left(\frac{1260}{108536\ x\ 4}\right)\ x\ 1.000.000$$

$$= 2902$$

And the total DPMO amount is

$$DPMO = \left(\frac{20201}{1400252\ x\ 4}\right)\ x\ 1.000.000$$

$$= 0{,}0030606\ x\ 1.000.000$$

$$= 3607$$

After knowing the DPMO value, the next step is to find out the sigma level value for the company. where the sigma level value is an indicator that describes the number of *defective products* as a reference in process assessment for the formula for finding the sigma value is:

$$Sigma\ Value = \ NORMSINV\frac{(1000000 - DPMO)}{(1000000)} + 1{,}5$$

For February week 1, the sigma value is

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$$Sigma\ Value = \ NORMSINV\frac{(1000000 - 2902)}{(1000000)} + 1{,}5 = 4{,}25$$

For the total sigma value, namely

$$Sigma\ Value = \ average\ of\ all\ calculated\ sigma\ values$$

A sigma value of 4.19 was obtained, which is the average of all calculated sigma values. The highest sigma value occurred in the 3rd week of February while the lowest value was in the 2nd week of March. Company PT. Indorama Teknologies *Complex* has reached the average level of the manufacturing industry, but the performance in the *cotton production process* still not optimal, So it is necessary to identify the factors that cause failures in the *cotton production process,* so that companies can improve company performance and value.

Analyze

***Fishbone* Diagram**

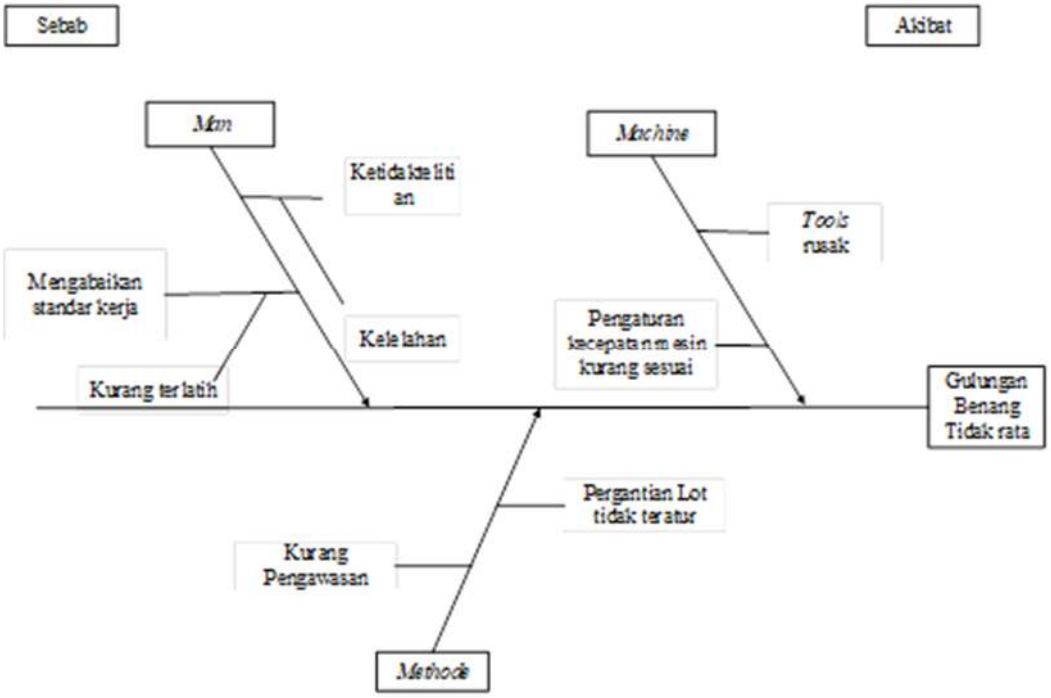

Figure 3. *Fishbone* Diagram Uneven Yarn Winding Defects

Diagram *(P – Chart)*

Table 6. Control P-Chart Data for Uneven Yarn Winding

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No	Date		Defect Eg (Colonoscopy Tidak rata)	Total Production (Kg)	Proportion	CL	UCL	LCL
1	Feb	Ke - 1	1860	108536	0,0171	0,0217	0,032	0,012
2		Ke - 2	2085	108916	0,0191	0,0217	0,032	0,012
3		Ke - 3	1716	108546	0,0158	0,0217	0,032	0,011
4		Ke - 4	2330	131815	0,0177	0,0217	0,032	0,013
5	Mar	Ke - 1	2121	109476	0,0194	0,0217	0,031	0,012
6		Ke - 2	3601	107398	0,0335	0,0217	0,032	0,014
7		Ke - 3	1964	108578	0,0181	0,0217	0,031	0,012
8		Ke - 4	2291	134416	0,0170	0,0217	0,031	0,013
9	Apr	Ke - 1	2379	107847	0,0221	0,0217	0,031	0,013
10		Ke - 2	2389	104070	0,0230	0,0217	0,031	0,013
11		Ke - 3	2374	105444	0,0225	0,0217	0,031	0,013
12		Ke - 4	3194	139010	0,0230	0,0217	0,032	0,014
Total			30343	1400252,0				

Source: Data processed 2023

Calculate the proportion of defects

$$Februari\ ke-1 = P = \frac{x}{n} = \frac{1860}{108536} = 0{,}0171$$

Information :

P = Proportion of errors in each sample

x = Number of defective products in each sample

n = Number of samples taken per week

Calculating the center line *(* CL)

$$CL = \overline{\mathrm{P}} = \frac{Total\ banyaknya\ produk\ cacat}{Total\ banyaknya\ sampel\ yang\ diambil}$$

$$CL = \overline{\mathrm{P}} = \frac{30343}{1400252} = 0{,}0217$$

Calculating *the Upper Control Limit* (UCL) or upper control limit

$Februari\ ke-1$:

$$UCL = \overline{\mathrm{P}} + 3\sqrt{\frac{\overline{\mathrm{P}}\,(1-\overline{\mathrm{P}})}{n}} = 0{,}0217 + 3\sqrt{\frac{0{,}0217(1-0{,}0217)}{1860}} = 0{,}032$$

Calculating *the Lower Control Limit* (L CL) or lower control limit

$Februari\ ke-1$:

$$LCL = \overline{\mathrm{P}} + 3\sqrt{\frac{\overline{\mathrm{P}}\,(1-\overline{\mathrm{P}})}{n}} = 0{,}0217 - 3\sqrt{\frac{0{,}0217(1-0{,}0217)}{1860}} = 0{,}012$$

From the results of the calculations in the table above, a control chart P is then created which can be seen in the following image:

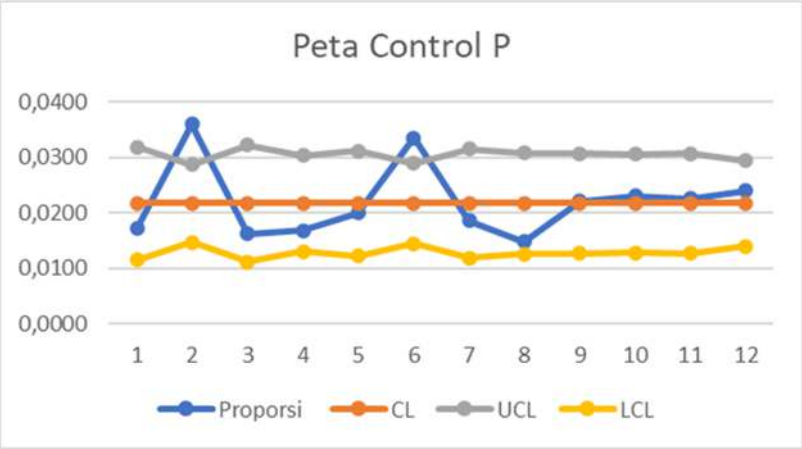

Figure 4. P Control Map Graphic Uneven Roll Defects

Based on the picture, it shows that there are processes that are not under control. There is some measurement data that is outside the *control* limits . Namely, the data that will be removed because it is outside the limits is data number 2 (February 2) and data number 7 (March 2). After the revision, the DPMO value was 3232 and the sigma value increased to 4.22, although it was still below 6, but there was an increase after the revision.

Using *Failure Mode and Effect Analysis* (FMEA)

In FMEA there are characteristics of *Mode of Failure* , *Cause of Failure* , *Effect of Failure* , *Frequency of Occurrence* , *Degree of Severity* , *Chance of Detection* . The resulting values are then put into a column ranging from 1-10 according to the table and this number is multiplied to obtain *a Risk Priority Number* (RPN) and will be the priority scale for problems that must be resolved first.

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Table 7. *Failure Mode and Effect Analyze* (FMEA) Uneven Yarn Winding defects

Failure Mode	Failure Cause	Effect Cause	Cause	SEV (S)	OCC (O)	DET (D)	RPN (SxOxD)	Rank
Cotton yarn Thick/thin	Pengaturan persepsian mesin kurang sesuai	Defect	Faulty mesh	5	4	5	100	1
	Ketidaktelitian	Defect	Kelalaian	4	3	4	48	3
	Mengalirnya Serat ke Kaca	Defect	Kurang Terkelih	3	3	8	72	2
	Pengaturan Let Gilik terlalu	Defect	Kurangnya pengawasan	4	3	5	60	4
Total							280	

FMEA for types of uneven thread roll defects can be determined by each RPN value. The RPN value chosen is the highest because the higher the RPN value, the higher the risk of failure occurring. From the table above, you can see the potential causes of failure in the components of tangled threads and dirty threads The ones with the largest RPN values are damaged tools and dirty machines with an RPN value of 100, both of which are the same as the machine, with the following calculation:

$$RPN = S\ X\ O\ X\ D$$

$$RPN = 5\ X\ 4\ X\ 5 = 100$$

Improve

This stage is a stage to perfect the performance of the current process, by making continuous improvements (*continuous improvement*). At this stage it is carried out using the 5W+1H method.

Table 8. 5W+1H

How many	What?	Why?	Who?	Where?	When?	How?
Kurangnya pemeriksaan mesin.	Melakukan pengawasan dan pemeliharaan jadwal perawatan mesin secara berkala	Mencegah terjadi defect yang ada	Bagian terkait di area Ring Frame	Pada bagian Ring Frame	Ketika mesin di operasikan dan terjadi kerusakan	Melakukan pengawasan secara berkala dan rutin dengan jadwal secara berkala

At the *improve* or repair stage, it is given to overcome the causes of defects in *cotton yarn products* , based on the 5W+1H analysis, the proposed improvement is strict supervision so that maintenance on the machine is carried out according to the schedule set by the company on a regular basis.

Controls

At this stage the researcher tries to provide suggestions for controlling and supervising the process in the implementation and improvement stages where the solution to the implemented problem will be controlled. This stage is the final operational stage, but in this study control cannot be carried out because the improvement stage is only a proposal.

CONCLUSION

The average sigma value of the yarn production process *cotton* is 4.19 sigma. because there was a value that exceeded the control limit, a revision was carried out which made the sigma value increase to 4.22. The sigma value still remains at level 4. There are four types of defects resulting from the cotton yarn production process, namely, dirty thread defects, uneven thread roll defects, tangled thread defects, and loose thread roll defects . There are three factors, namely, firstly , *Machine* , there is a high possibility of problems with the machine due to irregular maintenance in cleaning the machine according to schedule and workers' lack of attention to the machine in operation. Second , the *problems* faced by humans are due to lack of training, which results in ignoring work standards, as well as the relatively small number of workers, which results in fatigue, and finally, *Method* in the method section, there is a high probability that errors often occur, including irregular lot changes. Based on the 5W+1H analysis, the proposed improvement is strict supervision so that maintenance on the machine is carried out according to the schedule set by the company on a regular basis.

Suggestion

After conducting overall research, it can be seen that the sigma value obtained in the company is 4.22 from the total products produced with a DPMO value of 3232. This result is very good for a company. Companies should carry out regular maintenance, repairs and control according to a predetermined and periodic schedule and are expected to continue to improve product quality as well as carry out supervision.

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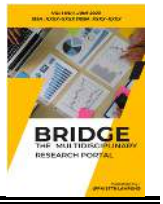

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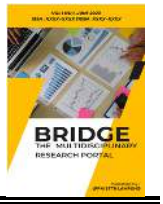

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