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Research Article

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Analysis of Process Capability Improvement in the Painting Cabinet Process of Polish Ebony (PE) Piano Parts with the DMAIC Method through the application of TQM: A Case Study in Piano Manufacturing Companies in Indonesia

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Abstract Entering Industry 4.0, quality is one of the guarantees provided and must be fulfilled by the company to customers. Quality is also an important indicator for companies to exist amid intense competition in the industrial world. Therefore, it is necessary to continually improve and improve product quality in accordance with customer specifications and needs. In the implementation there is still a piano that is produced is beyond the expected standard, especially in terms of paint thickness. To find out the quality of painting pianos, an examination of the painting piano process is carried out using a statistical control process which is a variable control map, determining the capability index in testing quality characteristics, and measuring sigma levels to determine the extent of the painting quality produced. Process capability objectives are knowing the process capability index in meeting the established specifications. The DMAIC method is used to determine and analyze Painting defects, especially in terms of paint thickness. Paint thickness in the Painting process is the most dominant problem, namely the number of Piano cabinet defects contained in the Painting process. The company has a process capability at the 3.37 sigma level. The Defect rate per Million Opportunities (DPMO) is 11,200 DPMO. With the application of Total Quality Management (TQM) after improvisation and proposed improvement ideas, the company experienced an increase in sigma level at the level of 3.85. with the DPMO conversion rate down to 9,200 DPMO.

Keywords Quality, Defect, Painting, Process Capability, DMAIC, DPMO, TQM, Improvement

Introduction

Since 2011, we have entered Industry 4.0, which is characterized by increased connectivity, interaction, and the boundary between humans, machines, and other increasingly converging resources through information and communication technology said Minister of Industry Airlangga Hartarto at the Socialization of Industry 4.0 Roadmap Implementation [1]. The industrial revolution 4.0 will open wider employment opportunities and build human jobs to be faster and easier, and also provide new opportunities and challenges for each country to survive in competitive global competition [2]. This has an impact on business competition that is increasingly high and sharp, both in the domestic market and in the international market. Good quality will result from a good process and in accordance with predetermined quality standards based on market needs. Innovations and applied technologies that improve efficiency and process quality mean improving the quality of the final product, it comes from business value, but this method can be applied in organizational activities [3]. Companies can produce quality products if they have implemented a quality management system by involving all aspects of the company that are integrated with each other [4]. One standardization of international quality that is the guideline of the company in the quality management system is the ISO 9001 certification standard [5]. Companies that have obtained ISO 9001: 2008 certification standards can be said to have achieved Total Quality Management (TQM) [6]. This is because the ISO 9001: 2008 certification standard is the foundation of

achieving TQM [7]. Yusof and Aspinwall [8] stated that the application of quality control techniques and tools as one of the critical success factors of TQM. The proper use and selection of quality control techniques and tools play an important role in supporting the improvement and development of quality improvement/improvement processes and the implementation of quality management systems [9, 10]. Prajogo [10] stated that the use of quality tools and techniques as a means to improve the quality and performance of companies has been widely known since people saw the successful application of companies in Japan. According to Conca et al. [11], the application of quality control techniques and tools as one of the critical success factors of quality improvement, and is also defined as an element in the process of continuous quality improvement. Based on these conditions the application of quality control techniques and tools in the company requires special attention in order to obtain some critical success factors so that they are more effective and efficient [4]. Based on the results of research by Conca et al. [11], shows that there is a relationship between the success of the company obtaining ISO 9001: 2008 standard certification on the application of good quality control techniques and tools as well. According to Curry and Kadasah [18], the quality improvement program was not successfully implemented, if the key success factors for the implementation of quality control techniques and quality management systems were not implemented in a balanced manner in achieving the objectives. Whereas according to Hairulliza et al. [19], the choice of quality control techniques and tools is influenced by three main factors. The three main factors are ease of use, able to measure product specifications, and able to increase productivity and quality. McQuater et al. [20] and Spring et al. [21] suggested that from top to low-level management, involved in solving quality problems with various techniques used, to form a mindset that they are part of a continuous improvement process. The application of good quality control techniques and tools will have a positive impact on improving company performance.

One piano manufacturing company produces high-quality products at affordable prices, good designs and the accuracy of the model and time of order are the main concerns to win the competition. That is what drives the company to make a piano in terms of design and attractive appearance because the shape and appearance are the first indicators that are determined by consumers in buying a product [23]. Without reducing the quality of the sound produced, the company carries out strict quality control on what matters can affect in terms of piano appearance, one of which is in the case of piano painting itself. Therefore Quality Assurance Department makes minimum standards against disability in terms of painting/painting produced. By working with the Process Control Department, an accurate and accurate information is generated for each manager, assistant manager and foreman painting on the number of painting defects found every day based on the type of defect that has been agreed upon. So that you can do kaizen regularly so that there is the continuous quality improvement for the next production. The formulation of this research problem is how the application of quality control in the Piano Painting process, in terms of paint thickness by using the DMAIC method in line with the application of TQM in the company. The objectives to be achieved in this research are: Identify defects along with the factors that cause the defective product to occur in the Painting Piano process, Provide recommendations for improvements to minimize defects in the Painting Piano process, Calculate DPMO, Level Sigma before and after the proposed improvement in the process Painting Piano in terms of paint thickness, in line with the application of TQM in the company.

Literature Review

Implementing innovation may require major organizational changes to evolve from closed-to-open-model innovation. For example, implementing innovative services can mean making changes to the organizational structure, employee training programs, and company procedures [12]. Six Sigma provides a general quantitative approach that applies to any process. For applications, it needs to be adjusted to the domain of the process through special measurements and analysis. Basically, this is a high-performance data-based approach to analyzing the roots of business problems and solving them. It connects business output directly with customer needs. Name, Six Sigma, derived from a measure of statistical process capability for customer specifications. For most managers and practitioners, Six Sigma is identical to the Define, Measure, Analyze, Improve and Control (DMAIC) methodologies and related toolkits. Six Sigma also provides an organizational framework by releasing and training process analysis (called Black Belts and Green Belts) that devotes undivided attention to

process improvement. User organizations have experienced significant savings by using Six Sigma [13]. Sigma is a measurement used to assess process performance and results of improvement efforts - ways to measure quality. Business uses sigma to measure quality because it is a standard that reflects the level of control over any process to meet the performance standards set for the process [14]. 3 of 14 Deming view: "Stop dependence on inspection" Instead of checking the product for quality after production, enter quality initially with production quality control because this will ensure that no raw material is wasted for quality. All inspections can be done is to destroy most of the damaged ones, which will be reworked or discarded. It's too broad and unsatisfactory. Quality comes from endlessly improving the process that makes the product [15]. In Six Sigma there are 5 phases of DMAIC (Define, Measure, Analyze, Improve, Control) which is a continuous improvement process towards the Six Sigma target. The DMAIC method is carried out systematically based on existing knowledge and facts. DMAIC is a closed-loop process that eliminates unproductive process steps, often focusing on new measurements and applying technology to improve quality towards the Six Sigma target [22]. DMAIC consists of five main stages [17]:

- Define is the first step in the Six Sigma approach. This step identifies important issues in the ongoing process.
- The measure is a follow-up to the Define step and is a bridge for the next step, Analyze. The measuring step has two main objectives, namely: Obtain data to validate and quantify problems or opportunities, Start touching facts and figures that provide clues about the root of the problem. The milestone in the measuring step is to develop the initial sigma size for the process that is being repaired.
- Analyze This step starts to enter into details, improves understanding of processes and problems, and identifies the root of the problem. In this step, the Six Sigma approach applies statistical tools to validate the root causes. The purpose of this stage is to find out how well the process is going on and identify the root causes that might be the cause of the variations in the process. To find out how well the process takes place, it is necessary to have a value or index, namely the Process Capability Index.
- Improve During this stage, ideas of improvements or solutions that may be implemented are explained.
- Control As part of the Six Sigma approach, there needs to be supervision to ensure that the desired results are in the process of being achieved.

Process Capability and DPMO, widely dispersed capability and performance indexes are measured based on general benchmarks of process capability or performance in relation to specific requirements [16]. Motorola's Six Sigma Process Control (Motorola Six Sigma Process Control) control approach allows a shift in the average (mean) value of the industrial process by ± 1.5σ, so that it will produce a level of discrepancy of 3.4 per million opportunities (3.4 DPMO = Defect Per Million Opportunities), meaning that every one million opportunities there will be a possibility of 3.4 nonconformities [16].

Methodology

Six Sigma methodology is built on Six Sigma metrics. Six Sigma practitioners measure and assess the process performance using DPMO and sigma. They apply the strict DMAIC (Define, Measure, Analyze, Improve, Control) methodology to analyze processes to eradicate unacceptable sources of variation, and develop alternatives to eliminate or reduce errors and variations. After improvements have been made, controls are put in place to ensure sustainable results. Using the DMAIC methodology, many organizations have made significant improvements in product and service quality and profitability over the past few years. The steps taken in processing data in this study are [14]:

1. Data processing with the concept of Statistical Process Control, that is by using variable control maps $\underline{X}$ and R. Control charts are used to determine the characteristics of the distribution of the data being studied.
2. Calculation of Process Capability is the ability of the process to meet specifications that have been determined by the company and ultimately will be able to meet customer satisfaction. Capability calculation is done by determining the Capability Index (Cp) of the process under study, Assessment criteria:
   - If Cp > 1.33, the process capability is very good.
   - If 1.00 p Cp ≤ 1.33, then the process capability is good, but it needs tight control if Cp approaches 1.00.
   - If Cp is < 1.00, then the process capability is low, so it needs to be improved through improved processes.

3. Calculation of Sigma Levels and DPMO values, The following are the steps that can be used in calculating sigma levels for variable data:
   a. Determine what process you want to measure.
   b. Determine the upper specification limit value (USL) and lower specification limit value (LSL).
   c. Determine the average value ($\bar{X}$), $\bar{X} = \frac{\sum_{i=1}^{n} X}{n}$
   d. Determine the standard deviation value (σ_0), $\sigma_0 = \frac{\bar{R}}{d_2}$
   e. Calculates the probability of defects that are above the USL value per one million opportunities (DPMO).
   $$DPMO\ USL = P\ \lfloor z \geq (USL - \bar{X})\ /\sigma_0 \rfloor\ x\ 1.000.000$$
   f. Calculate the possibility of defects that are above the value of MSM per one million opportunities (DPMO).
   $$DPMO\ LSL = P\ \lfloor z \leq (LSL - \bar{X})\ /\sigma_0 \rfloor\ x\ 1.000.000$$
   g. Calculate defects per one million opportunities (DPMO).
   Total DPMO = DPMO USL + DPMO LSL
   h. Convert DPMO values into sigma values using the sigma table.

Result and Discussion

One of the manufactures of piano instrument manufacturing companies in Indonesia produces pianos which are mostly for 99% overseas customers for the export market. In making the piano in a company there are four parts that are interrelated with one another. The four sections are Wood Working, Painting, Sanding-Buffing, and Assembly. The four sections can be seen in the piano making plot in figure 1. There are 4 parts of production that are interrelated one another with the four parts are woodworking, painting, sanding buffing, and assembly. The fourth section has data on each defect that will be reported and followed up by the company each month for the repair process. The defect data that has been observed from February to April 2017 shows the defects of the four sections can be seen in table 1.

Table 1: Data defect February to April 2017

Process Type	Total Defect
Woodworking	275
Sanding Buffing	271
Painting	653
Assembly	227

Define phase

Define is a phase of determining problems, determining customer requirements, and knowing CTQ (Critical to Quality). The purpose of the definition phase is to determine the problems that exist in the company, there are still defects in each part of the process for making the piano, especially in the painting section that shows the size of the paint thickness in the painting process that has not met the specifications of the quality standards set by the company and often experience various variations in quality and sometimes are outside the established standards. This, of course, is detrimental to the company because the company expects the products produced in accordance with the requirements set. At this stage also determined the problems of factors that affect defects in the painting process, especially for the size of the paint thickness in the painting process that has not met the specifications of the quality standards set by the company. The defect in the painting section shows the highest value from the other three parts, this shows that in the part of the painting that will be selected for the calculation and improvement that will be proposed for the company's consideration. Based on observations that have been made in the painting section, the following data on the types of defects in daily painting from February to April 2017 can be seen in Table 2.

Based on the painting defects that have been observed the thickness of the paint has a lot of influence on the types of defects in the painting process. The data used is measurement data and examination of paint thickness in units of µm in the painting process. Checks and measurements are carried out with the help of several tools, namely panametrics (Coating Thickness Gauge), transducer, couplant, and charger. The specifications that the company wants to get the best results are as follows. Specifications of paint thickness in the process of painting

LSL = 320 µm and USL = 380 µm to solve the problem then the researcher looked for sample data measurements and examination of paint thickness in the painting process (µm) in February and April 2017. The sample measurement and inspection of paint thickness in the process painting (µm) can be seen in table 3.

Table 2: Types of Painting Defects Period February to April 2017

No	Types of defects painting February to April 2017	Number of Defective Products (Units)			Total
1	Less Sanding	315	324	284	923
2	Muke Surface	318	396	338	1.052
3	Dekok	242	199	81	522
4	Gelt	190	154	135	479
5	Obake	166	141	146	453
6	Pinhole	83	77	18	178
7	Broken	58	53	59	170
8	Dirty	37	29	30	96
9	Muke Mentori	14	20	18	52
10	Worm	7	6	16	29
11	Muke Edge	7	5	3	15
12	Plot	6	12	6	24

Table 3: Paint thickness data (µm) from February to April 2017

No	Point 1			Point 2			Point 3		
	Left	Center	Right	Left	Center	Right	Left	Center	Right
1	351	341	354	388	342	337	402	339	343
2	344	357	340	387	354	360	405	385	350
3	345	355	352	371	345	352	333	345	343
4	335	347	344	339	342	351	336	346	338
5	344	347	340	343	346	347	348	355	339
6	383	344	349	348	345	367	353	350	341
7	347	339	351	347	341	354	349	348	334
8	364	339	349	348	357	360	344	380	366
9	386	336	343	359	355	363	341	346	338
10	354	340	337	371	347	355	369	356	337
11	364	334	358	345	347	353	344	354	343
12	365	348	355	339	344	349	351	353	339
13	358	353	350	341	339	344	349	390	407
14	354	349	348	334	339	341	353	350	341
15	356	344	380	366	336	369	349	348	334
16	347	341	346	338	340	344	349	347	355
17	353	369	356	337	334	351	345	347	353
18	364	344	354	343	348	349	339	354	349
19	378	351	353	339	347	344	341	339	344
20	412	349	390	403	364	362	334	339	341
21	367	366	362	339	339	343	366	336	369
22	387	338	389	385	348	350	338	340	344
23	347	337	347	333	345	343	387	338	389
24	341	343	343	336	346	338	347	337	347
25	352	339	354	339	342	349	341	343	346

Measure phase

The measure is the phase of measuring the current level of performance. At this stage, what will be done is. Creating a control chart $\underline{X}$ and R, calculating the Sigma Level that the company has achieved at this time. Measurements and checks will be made on the paint thickness in the painting process (µm) which has the greatest defect in the painting process. The determination of CTQ (Critical to Quality) is determined based on the specific needs of the customer. Where these specific needs are based on the output requirements that must be free from defects. In the define stage, it is known that customers, namely the assembly process, want the

condition of the painting results to be really good visually. Because customer painting is very selective about the physical appearance of the piano. There are several types of defects found in the piano painting process. However, in this observation, the potential CTQ determination is focused on the five largest types of defects based on the number from February to April 2017. The selection of CTQ is done because by anticipating the characters that have the most defects can significantly reduce defects, can be seen in table 4. and Pareto diagrams the following.

Table 4: Five types of piano painting defects Period February to April 2017

No	Type of defect	Frequency	Percentage of total (%)	Cumulative percentage (%)
1	Less Sanding	923	26,92	26,92
2	Muke Surface	1052	30,68	57,60
3	Dekok	522	15,22	72,82
4	Gelt	479	13,97	86,79
5	Obake	453	13,21	100,00
Total		3429	100,00	

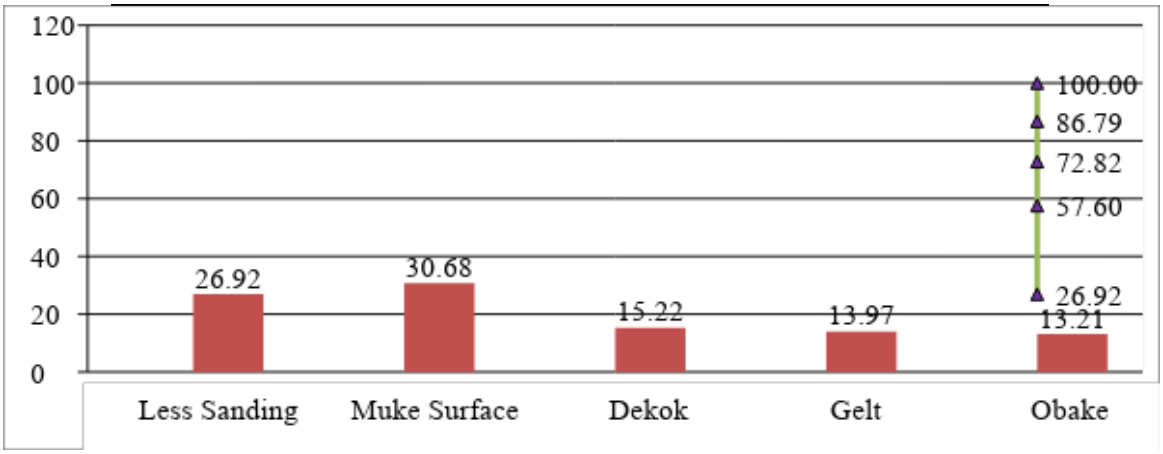

Figure 1: Pareto diagram of the largest type of defect

From the Pareto diagram above, it can be seen that the 5 biggest types of defects are Less Sanding, Muke Surface, Dekok, Gelt, and Obake. Thus the potential key CTQ assigned to the five types of defects are strongly influenced by Painting (µm) paint thickness. Furthermore, the creation of a control map aims to see whether the process that is running is within the limits of statistical control. Because the variations that arise in the piano painting process are influenced by the thickness of Painting paint (µm). Therefore, the control chart that is suitable for use in this measurement is the control map for variable data, namely the $\underline{X}$ and R control maps. In making this $\underline{X}$ and R control map. With the measurement data of Painting paint thickness (µm) then the calculation of the range and control limits is calculated. The results of measurement and examination of paint thickness in the Painting (µm) process can be seen in table 5.

Table 5: Processing of paint thickness data in the Painting (µm) process

S.	Point 1			Point 2			Point 3			Left	Center	Right	L	C	R
No.	L	C	R	L	C	R	L	C	R	X-Bar	X-Bar	X-Bar	R1	R2	R3
1	351	341	354	388	342	337	402	339	343	380,33	340,67	344,67	51	3	17
2	344	357	340	387	354	360	405	385	350	378,67	365,33	350,00	61	31	20
3	345	355	352	371	345	352	333	345	343	349,67	348,33	349,00	38	10	9
4	335	347	344	339	342	351	336	346	338	336,67	345,00	344,33	4	5	13
5	344	347	340	343	346	347	348	355	339	345,00	349,33	342,00	5	9	8
6	383	344	349	348	345	367	353	350	341	361,33	346,33	352,33	35	6	26
7	347	339	351	347	341	354	349	348	334	347,67	342,67	346,33	2	9	20
8	364	339	349	348	357	360	344	380	366	352,00	358,67	358,33	20	41	17
9	386	336	343	359	355	363	341	346	338	362,00	345,67	348,00	45	19	25
10	354	340	337	371	347	355	369	356	337	364,67	347,67	343,00	17	16	18
11	364	334	358	345	347	353	344	354	343	351,00	345,00	351,33	20	20	15
12	365	348	355	339	344	349	351	353	339	351,67	348,33	347,67	26	9	16

13	358	353	350	341	339	344	349	390	407	349,33	360,67	367,00	17	51	63
14	354	349	348	334	339	341	353	350	341	347,00	346,00	343,33	20	11	7
15	356	344	380	366	336	369	349	348	334	357,00	342,67	361,00	17	12	46
16	347	341	346	338	340	344	349	347	355	344,67	342,67	348,33	11	7	11
17	353	369	356	337	334	351	345	347	353	345,00	350,00	353,33	16	35	5
18	364	344	354	343	348	349	339	354	349	348,67	348,67	350,67	25	10	5
19	378	351	353	339	347	344	341	339	344	352,67	345,67	347,00	39	12	9
20	412	349	390	403	364	362	334	339	341	383,00	350,67	364,33	78	25	49
21	367	366	362	339	339	343	366	336	369	357,33	347,00	358,00	28	30	26
22	387	338	389	385	348	350	338	340	344	370,00	342,00	361,00	49	10	45
23	347	337	347	333	345	343	387	338	389	355,67	340,00	359,67	54	8	46
24	341	343	343	336	346	338	347	337	347	341,33	342,00	342,67	11	9	9
25	352	339	354	339	342	349	341	343	346	344,00	341,33	349,67	13	4	8

From the observation and calculation of paint thickness, 3 points are used for data retrieval, namely point L (left), C (center), and R (right). The three points are the left, center and right where the three parts have different thicknesses.

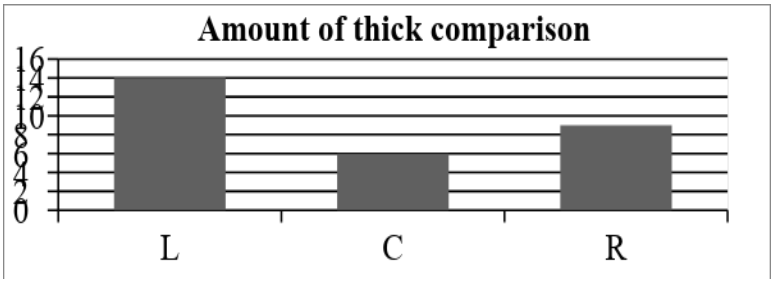

Figure 2: Comparison of paint thickness

Limit of Paint Thickness Control Before Repair

Of the three points observed are points L, C, and R Selected part L (left) because it has a thickness of more than two other parts. The following table limits calculation can be seen in Table 6.

Table 6: Calculation of Control Limit

S. No.	Measurement in the upper sample unit		
	L1	L2	L3
1	345	371	333
2	335	339	336
3	344	343	348
4	383	348	353
5	347	347	349
6	364	348	344
7	386	359	341
8	354	371	369
9	364	345	344
10	365	339	351
11	358	341	349
12	354	334	353
13	356	366	349
14	347	338	349
15	353	337	345
16	364	343	339
17	378	339	341
18	367	339	366
19	387	385	338
20	347	333	387
21	341	336	347
22	352	339	341

Based on the results of the calculation of the upper control limit value and the lower control limit can be described control chart $\underline{X}$ and R of paint thickness (µm). Control chart $\underline{X}$ and R can be seen in Figure 3. and 4. The following.

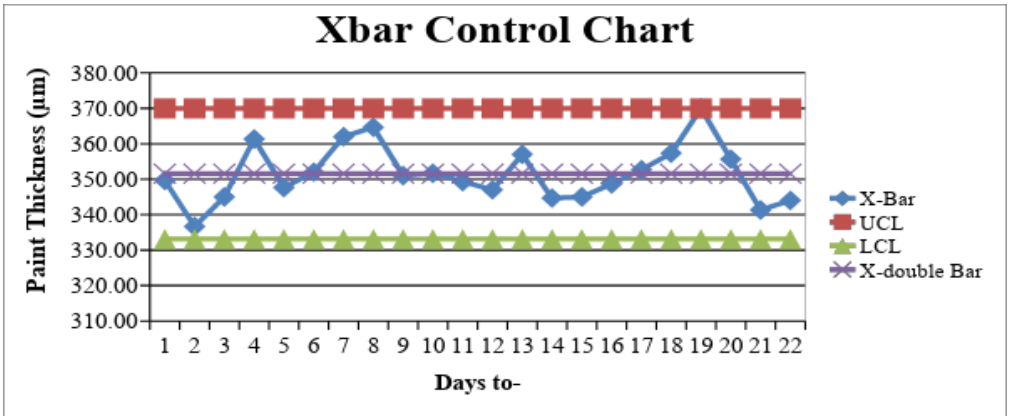

Figure 3: $\underline{X}$ Chart for Paint Thickness (µm)

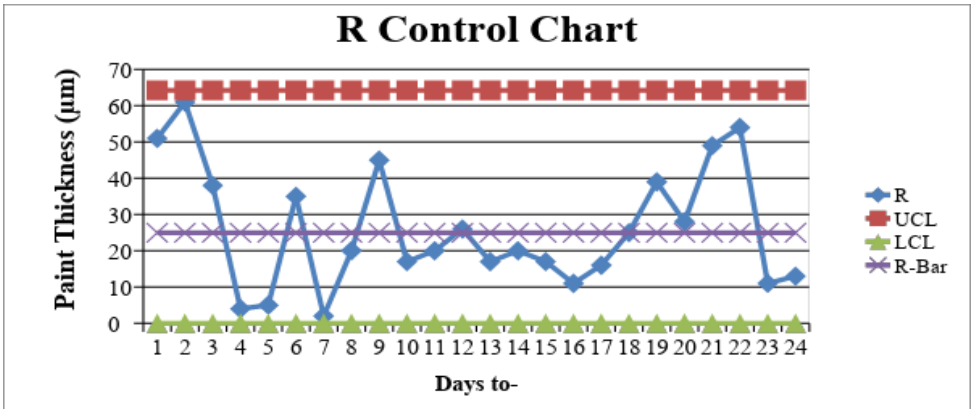

Figure 4: R Chart for Paint Thickness (µm)

Calculation of Cp and Cpk values before Repair

In the calculation of Cp and Cpk you must know the value of d_2. The price of d_2 is 1.693 for the sub group 3. The specifications allowed by the company to meet the specifications of the paint thickness in the process of painting LSL = 320 µm and USL = 380 µm.

Calculation of process capabilities for paint thickness in the Painting (µm) process are as follows.

$$\sigma = \frac{\underline{R}}{d_2} \quad \sigma = \frac{24.96}{1.693} \quad \sigma = 14.47$$

$$C_p = \frac{USL - LSL}{6\sigma} \quad C_p = \frac{380 - 320}{6(14.47)} \quad C_p = 0.69$$

The value of Cp = 0.69 indicates that the process is less capable to meet the specifications of the paint thickness in the Painting (µm) process because the value of Cp < 1. So that its performance needs to be improved through process improvement.

$$C_{pu} = \frac{USL - \bar{\bar{X}}}{3\sigma} \quad C_{pu} = \frac{380 - 351.56}{3(14.47)} \quad C_{pu} = 0.65$$

$$C_{pl} = \frac{\bar{\bar{X}} - LSL}{3\sigma} \quad C_{pl} = \frac{351.56 - 320}{3(14.47)} \quad C_{pl} = 0.73$$

$$C_{pk} = \{(Cpu) or\ (Cpl)\} \quad C_{pk} = \min\{(0.65 \text{ or } (0.73)\} \quad C_{pk} = 0.65$$

This Cpk = 0.65 value indicates that the process of producing a product that cannot meet the Upper Specification Limit (USL) for the specification of paint thickness in the Painting (µm) process is because the value is in the Cpk < 1.00.

Calculation of Sigma Level before Repair

To measure the sigma level, the following steps are used:

1. Calculate the possibility of defects that are above the value of USL per million opportunities (DPMO).

$$DPMO\ USL = P\ \lfloor z \geq (USL - \bar{X})\ /\sigma_0 \rfloor\ x\ 1.000.000$$
$$DPMO\ USL = P\ \lfloor z \geq (380 - 351.56)\ /14{,}47 \rfloor\ x\ 1.000.000$$
$$DPMO\ USL = \lfloor 1 - P(z \leq 2.07) \rfloor\ x\ 1.000.000$$
$$DPMO\ USL = \lfloor 1 - 0.9808 \rfloor\ x\ 1.000.000$$
$$DPMO\ USL = 0.0192\ x\ 1.000.000$$
$$DPMO\ USL = 19.200$$

2. Calculate the possibility of defects that are below the value of LSL per one million opportunities (DPMO).

$$DPMO\ LSL = P\ \lfloor z \leq (LSL - \bar{X})\ /\sigma_0 \rfloor\ x\ 1.000.000$$
$$DPMO\ LSL = P\ \lfloor z \leq (320 - 351.56)\ /14{,}47 \rfloor\ x\ 1.000.000$$
$$DPMO\ LSL = P \lfloor z \leq -2.29 \rfloor\ x\ 1.000.000$$
$$DPMO\ LSL = \lfloor 1 - 0.9890 \rfloor\ x\ 1.000.000$$
$$DPMO\ LSL = 0.011\ x\ 1.000.000$$
$$DPMO\ LSL = 11.000$$

3. Calculate defects per one million opportunities.

Total DPMO = DPMO USL + DPMO LSL

Total DPMO = 19.200 +11.000

Total DPMO = 30.200

4. Convert DPMO values into sigma values by using the sigma table in the attachment. By using the DPMO conversion table to the sigma value, it is known that the DPMO value of 30,200 is found at the level of 3.37 sigma.

Analyze Phase

The analysis phase is the phase of finding and determining the root of the problem. At this stage an analysis of the data that has been obtained. This data analysis needs to be done to find out the sources and root causes of the deviation from existing product specifications. Where the product specification deviations that occur will have an impact on the quality of the Painting piano that has been produced. In this case, the cause of the thickness of the Painting paint on the piano cabinet is outside the specifications due to several things. For more details can be seen in the following causal diagram:

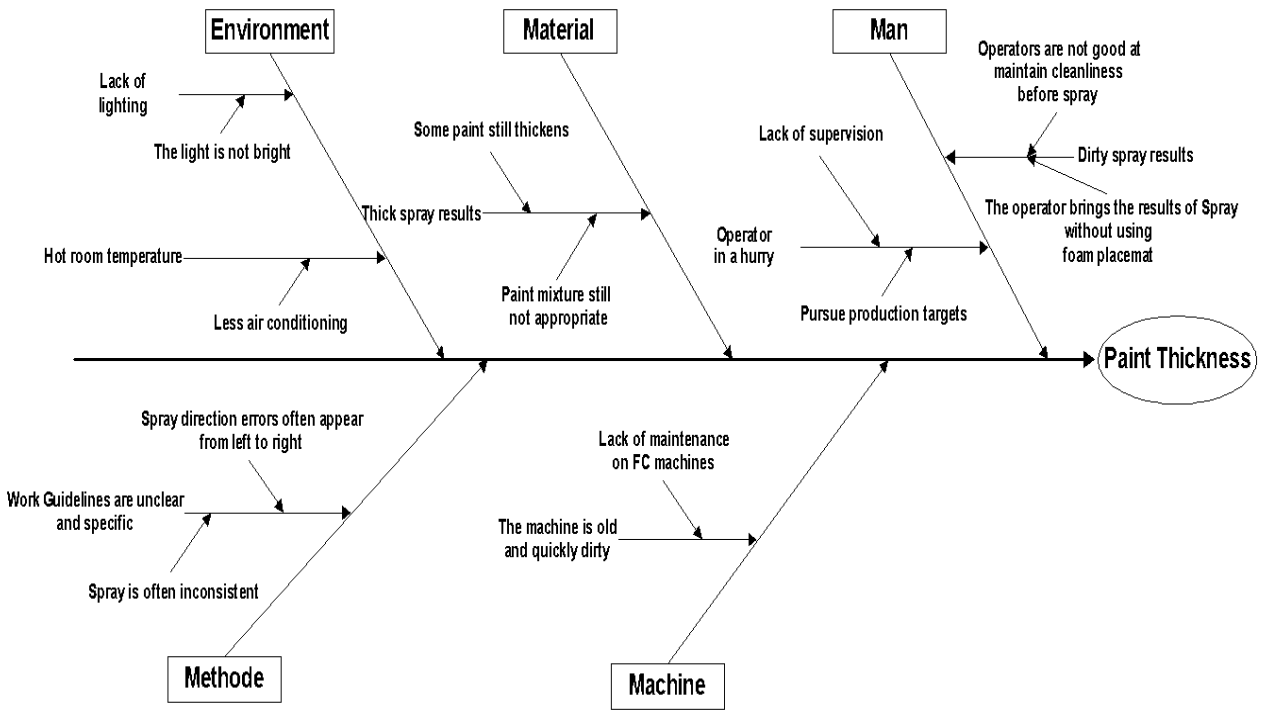

Figure 5: Cause and Effect Diagram for paint thickness (µm) Painting process

Table 7: Causes of Painting paint thickness

No.	Factor	Cause
1	Man	The operator in the previous spray was not cleaned so that the spray process was dirty. Cleaning was still lacking before. Operators often make mistakes, Lack of accuracy (Human Error), rush, and target.
2	Material	How to bring the results of the spray process is not good and there are other objects that can stick. The results of the spray are still less than optimal because there is still a thick paint and poor paint mixture. The composition of raw materials uses new paint because there are certain products and there are still many that need to be adjusted.
3	Environment	Lack of lighting at the time of inspection before the cabinet is sent to the next process. Hot temperatures in the spray room due to lack of air conditioning.
4	Method	There is often a mistake in the direction of the spray that does not match the Work Instructions and is less consistent. Spray from left to right repeatedly and can accumulate on the left to become thick.
5.	Machine	The machine that has aged causes dirty fast and the need to set up a machine that takes time when spraying in the painting section. Lack of maintenance on older and older machines.

Improve phase

After the source or root cause of quality problems is identified, it is necessary to look for actions that can be taken in an effort to reduce product specification deviations that occur. From the root of the problem obtained, then some corrective steps can be taken in table 8.

Table 8: Development of Action Plans for improvement

Factor	What	Why	Where	How	When	Who
Man	Cleaning before the spray is still not good	Because there are still dirty spray results and often there are small objects that stick	Painting process and flow coater spray machine	Provide job training, especially during the spray process	Adjusted by the relevant supervisor	Supervisor and Operator of flow coater and spray machines
	Operators rush and target	Because there are spray results that are less even and look often to rest	Painting process and flow coater spray machine	Provide direction and adjust the time to rest	Every 1-week	Supervisor and Operator of flow coater and spray machines
	the results of the spray are often dirty	Because the way to bring spray results is not good	Painting process and flow coater spray machine	Provide guidance on how to bring spray results so as not to get dirty	Tailored by the relevant supervisor and painting manager	Supervisor and Operator of flow coater and spray machines
Material	Paint mixture is not right	Because there is still paint thickening	Painting process and flow coater spray machine	Make the appropriate dose for the paint mixture	Before the process of spray painting	Supervisor and Operator of flow coater and spray machines

	The use of new paint	Because there are thick spray results	Painting process and flow coater spray machine	First experiment for new paint before use	Each uses new paint	Supervisor and Operator of flow coater and spray machines
Machine	Dirty machine quickly	Because the machine is old and needs to be set up	Painting process and flow coater spray machine	Regular maintenance and cleaning	Every day before and after use	Supervisor and Operator of flow coater and spray machines
	Lack of engine maintenance	Because it must always be reset again	Painting process and flow coater spray machine	Planning to replace new spare parts for better	Tailored by the relevant supervisor and painting manager	Supervisor and Operator of flow coater and spray machines
Environment	Lack of lighting	Because the lamp position is far and dim	Painting process and flow coater spray machine	Perform bright lamp replacement and good position	Every 3 months	Supervisor and Operator of flow coater and spray machines
	Hot room temperature	Because it interferes with the results of the spray painting process	Painting process and flow coater spray machine	Maintain indoor temperature, with air conditioning	Every temperature is outside the room temperature limit	Supervisor and Operator of flow coater and spray machines

Based on tables 7 and 8 there are various causes that cause the occurrence of painting paint thickness on piano cabinets that are outside the specifications, then given an overview of the action plan, improvements are needed to eliminate these causes. Action plans for improvement ideas can be seen in table 9.

Table 9: Improvements to specifications of paint thickness

No.	Proposed improvement ideas
1.	Providing training (training) on Work Guidelines to new Operators who are not experienced in Painting machines, manual spray and spray using Flow Coater machines.
2.	Create a new work section that is tasked with monitoring and re-checking employee performance so as to reduce errors caused by human error and provide more frequent direction to the machine operator to work properly.
3.	It is necessary to first test the use of new paint on certain products and adjust to the needs.
4.	Re-examine raw materials received from suppliers more thoroughly and check whether they meet the specified specifications before being used in the next process.
5.	The company needs to provide and add lighting equipment for the part of the painting process so that when checking the results of the spray can be maximum. Cleansing with a watery mop is done every 2 hours by general service.
6.	The company must immediately provide the right sanding training to get maximum results.
7.	Work instructions are given in writing with a detailed oral explanation, namely by carrying out regular

	briefings at the beginning and end of the work. As well as paying attention to the results of the spray, make sure it is in accordance with the specified specifications.
8.	Operators must check the readiness of the machine carefully before use and also when it is used. Give hot water to the faucet to warm the paint.
9.	Perform routine maintenance of the engine, not only when the engine is damaged (preventive maintenance). And also maintain the cleanliness of the engine.

In its implementation, the application of Industrial TQM in the company has successfully received ISO 9001 and ISO 14001 management certificates, as a realization that the company has implemented Total Quality Management (TQM). So the company implements ISO 9001 and ISO 14001 management systems with a high sense of responsibility and awareness and is focused on:

a. Fulfillment of customer requirements, applicable environmental laws and other requirements.
b. Improving product quality and the environment.
c. Minimizing the risk of environmental pollution and controlling the use of natural resources.
d. Quality improvement of supply goods through cooperation with principals and suppliers.
e. Continuously improving human resources through training at every level of employees.
f. Run a quality and environmental management system consistently and continuously.
g. Improved understanding and awareness of the quality and environment of each employee. All employees of the Company are responsible and faithfully carry out the quality and environmental management system actively in the improvement and development needed in accordance with their duties.

Control phase

The Control Phase is the last stage in improving quality with the DMAIC method. At this stage the results of quality improvement are documented, processes that have been improved, standardized and must always be improved. To find out about the quality improvement, the results of the confirmation confirmation above will be recalculated. The results of improvisation measurements and testing of paint thickness in the Painting (µm) process can be seen in table 10.

Table 10: Processing of Results Data Improving the thickness of paint (µm)

	L1	L2	L3	Total	Xbar	R
1	348	334	337	1.019	339,67	14
2	342	338	336	1.016	338,67	6
3	360	345	352	1.057	352,33	15
4	339	342	351	1.032	344,00	12
5	343	346	351	1.040	346,67	8
6	348	345	367	1.060	353,33	22
7	347	341	354	1.042	347,33	13
8	348	357	343	1.048	349,33	14
9	351	355	347	1.053	351,00	8
10	349	347	355	1.051	350,33	8
11	345	334	353	1.032	344,00	19
12	348	344	349	1.041	347,00	5
13	341	339	344	1.024	341,33	5
14	334	339	341	1.014	338,00	7
15	346	336	345	1.027	342,33	10
16	338	340	344	1.022	340,67	6
17	337	334	351	1.022	340,67	17
18	343	348	349	1.040	346,67	6
19	339	347	344	1.030	343,33	8
20	339	356	347	1.042	347,33	17
21	337	339	343	1.019	339,67	6
22	342	354	351	1.047	349,00	12
23	340	345	353	1.038	346,00	13
24	336	346	338	1.020	340,00	10
25	339	345	349	1.033	344,33	10

Control Limit Calculation of Improvisation Results

To determine the process capability, the control limits for paint thickness in the Painting (µm) process are determined by observing the data $\underline{X}$ and R as shown in the following table for data of 25 samples.

Table 11: Limits of Control of Results of Improved Actual Data

	Xbar	R
1	339.67	14
2	338.67	6
3	352.33	15
4	344.00	12
5	346.67	8
6	353.33	22
7	347.33	13
8	349.33	14
9	351.00	8
10	350.33	8
11	344.00	19
12	347.00	5
13	341.33	5
14	338.00	7
15	342.33	10
16	340.67	6
17	340.67	17
18	346.67	6
19	343.33	8
20	347.33	17
21	339.67	6
22	349.00	12
23	346.00	13
24	340.00	10
25	344.33	10
Total	8623.00	271

Based on the results of the calculation of the upper control limit value and the lower control limit can be described control chart $\underline{X}$ and R of paint thickness (µm). Control chart $\underline{X}$ and R can be seen in figure 6 and figure 7.

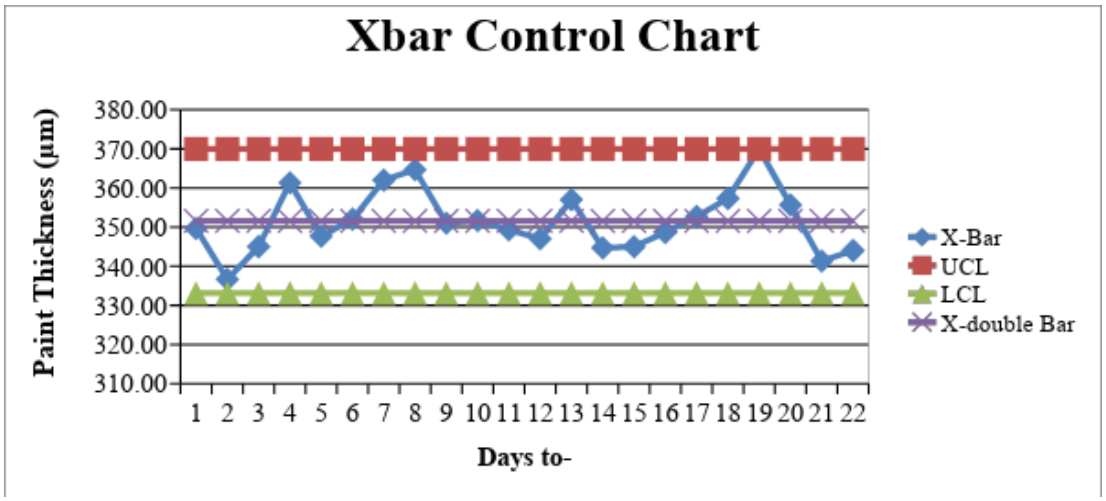

Figure 6: $\underline{X}$ Improvisation Result Chart for paint thickness (µm)

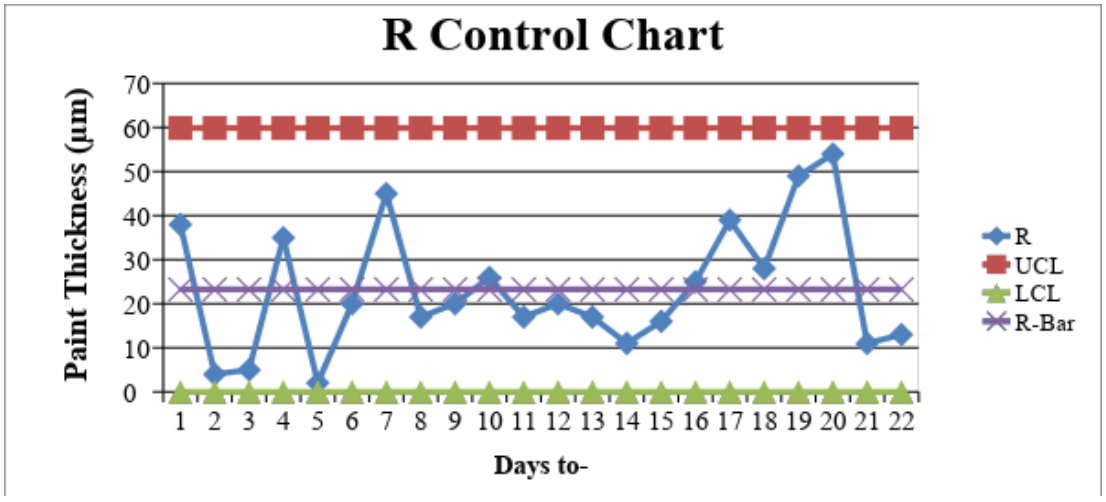

Figure 7: R Chart of Improvisation Results for paint thickness (µm)

Calculation of Cp and Cpk Results of Improvisation

In the calculation of Cp and Cpk, you must know the value of d_2. The value of d_2 is 1.693 for the subgroup 3. The specifications used by the company to meet the specifications of paint thickness (µm) are LSL = 320 µm and USL = 380 µm.

Process capability calculations for paint thickness (µm) are as follows.

$$\sigma = \frac{\bar{R}}{d_2} \quad \sigma = \frac{10.84}{1.693} \quad \sigma = 6.40$$

$$C_p = \frac{USL - LSL}{6\sigma} \quad C_p = \frac{380 - 320}{6(6.40)} \quad C_p = 1.04$$

The value of Cp = 1.04 indicates that the process is capable of meeting the specifications of the paint thickness (µm) because of the value of Cp between 1.00 ≤ Cp ≤ 1.33. And experience an increase of the Cp value before repair.

$$C_{pu} = \frac{USL - \bar{\bar{X}}}{3\sigma} \quad C_{pu} = \frac{380 - 344.92}{3(6.40)} \quad C_{pu} = 1.83$$

$$C_{pl} = \frac{\bar{\bar{X}} - LSL}{3\sigma} \quad C_{pl} = \frac{344.92 - 320}{3(6.40)} \quad C_{pl} = 1.29$$

$$C_{pk} = \{(Cpu) or\ (Cpl)\} \quad C_{pk} = \min\{(1.83) \text{ or } (1.29)\} \quad C_{pk} = 1.29$$

Cpk = 1.29, this shows that the process of producing products that meet the Lower Specification Level (LSL) and Upper Specification Limit (USL) paint thickness (µm) because the value is in the criteria, 1.00 ≤ Cpk ≤ 1.33.

Calculation of Sigma Level Results of Improvisation

1. Calculate the possibility of defects that are above the value of USL per million opportunities (DPMO).

$$DPMO\ USL = P\ \lfloor z \geq (USL - \bar{\bar{X}})/\sigma_0 \rfloor\ x\ 1.000.000$$
$$DPMO\ USL = P\ \lfloor z \geq (380 - 344.92)/6.40 \rfloor\ x\ 1.000.000$$
$$DPMO\ USL = \lfloor 1 - P(z \leq 2.36) \rfloor\ x\ 1.000.000$$
$$DPMO\ USL = \lfloor 1 - 0.9909 \rfloor\ x\ 1.000.000$$
$$DPMO\ USL = 0.0091\ x\ 1.000.000$$
$$DPMO\ USL = 9.100$$

2. Calculate the possibility of defects that are below the value of LSL per one million opportunities (DPMO).

$$DPMO\ LSL = P\ \lfloor z \leq (LSL - \bar{\bar{X}})/\sigma_0 \rfloor\ x\ 1.000.000$$
$$DPMO\ LSL = P\ \lfloor z \leq (320 - 344.92)/6.40 \rfloor\ x\ 1.000.000$$
$$DPMO\ LSL = P \lfloor z \leq -3.89 \rfloor\ x\ 1.000.000$$
$$DPMO\ LSL = \lfloor 1 - 0.9999 \rfloor\ x\ 1.000.000$$

$$DPMO\ LSL = 0{,}0001\ x\ 1.000.000$$
$$DPMO\ LSL = 100$$

3. Calculate defects per one million opportunities.
   DPMO Total = DPMO USL+DPMO LSL
   DPMO Total = 9.100+100
   DPMO Total = 9.200
4. Convert DPMO values into sigma values by using table Z. Using the DPMO conversion table to the sigma value it is known that the DPMO value is 9,200 in the 3.85 sigma level.

Comparison of DPMO and Level Sigma

The objective is compared to the DPMO value and sigma level before and after the improvement, namely to find out the magnitude of the decline and increase that occurs after corrective actions are implemented in the process. The amount of DPMO and sigma level before and after repairs are shown in the following table:

Table 12: Comparison of DPMO and Sigma Level Before and After Repair

No.	Baseline Performance	Value		Difference	Information
		Before Repair	After Repair		
1.	DPMO	11.200	9.200	2.000	Down
2.	Sigma Level	3,37	3,85	0,48	Go up

Based on Table 12, it is known that DPMO experienced a significant decrease after repairs were made. The amount of DPMO decrease after repairs are 2,000. Comparison of DPMO before and after repairs can be seen in the following figure.

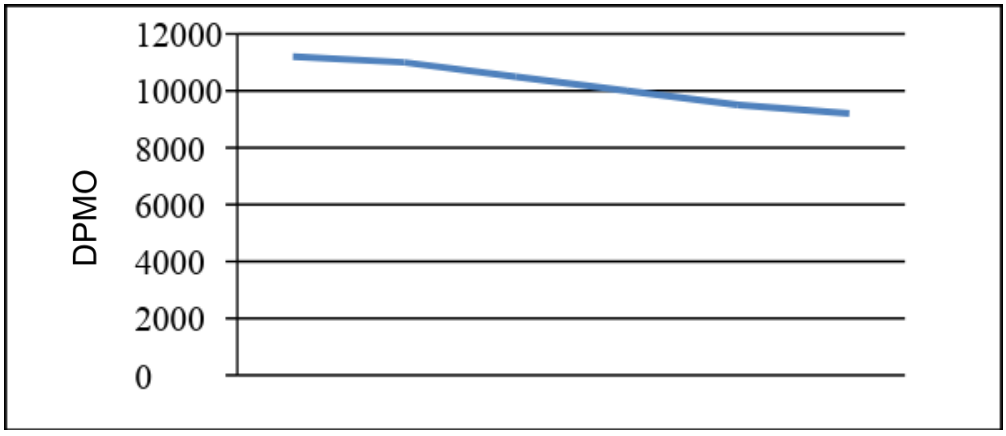

Figure 8: Comparison of DPMO Before and After Repair

Furthermore, based on table 12 it is known that the sigma level has increased after the improvement is made. The magnitude of the increase in sigma level after repairs is 0.48. Comparison of sigma level values before and after repairs can be seen in the following figure:

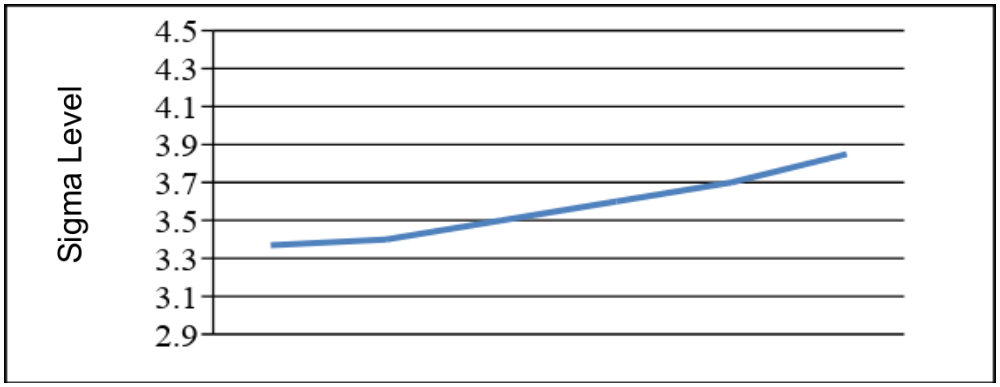

Figure 9: Sigma Level Comparison Before and After Repair

Conclusion

Based on the data that has been collected, processed and analyzed beforehand, it can be concluded as follows: The measurement and calculation results obtained the value of process capability for Painting paint thickness on piano cabinets of 1.04. And has given an increase compared to the value of the previous process capability of 0.65. With an increase of 37.5%. And it can be said that the painting process on the piano cabinet, especially in terms of the thickness of the paint has been able to produce products that meet the desired specifications. Sigma value for Painting paint thickness in the piano cabinet is 3.85 with DPMO of 9,200. Providing an increase in sigma value which is quite influential on the quality of Painting on the piano cabinet from the previous sigma value of 3.37 with DPMO of 11,200. The corrective actions applied to the process proved to be able to reduce the DPMO and increase the level of sigma, even though the magnitude of the decline and increase was not too significant. This is quite reasonable considering that Six Sigma is not an instant approach, but a systematic approach used to improve processes continuously. Thus, further improvements are needed in the process to improve performance in the future. The company can continuously improve continuous quality through the application of Total Quality Management to the level of six sigma (6σ).

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