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QUALITY IMPROVEMENT IN THE MOLDING MACHINE PROCESS WITH SIX SIGMA APPROACH AND DIGITALIZATION IN THE AUTOMOTIVE COMPONENT INDUSTRY

Yaman Parid[1], Hernadewita Hendra[2]

[1] Department of Industrial Engineering, Faculty of Engineering, University Mercu buana Jakarta, 10340 Jakarta, Indonesia
[2] Department Mechanical Engineering, Faculty of Engineering, University Sultan Ageng Tirtayasa Banten, 42124 Banten, Indonesia

Corresponding author: Hernadewita Hendra, hernadewita@mercubuana.ac.id

Abstract: The increasing market needs in the automotive industry affect the automotive component industry. So it is necessary to support the achievement of automotive industry sales. Industry automotive components most use molding machine production lines. But in the process, many experienced several problems, namely defective products due to unstable mold temperature factors. Quality improvement research was carried out on the process of a 150-ton hydraulic type vertical type molding machine that makes the product keypad design 021#1 with a six sigma and digitalization approach. The results of the stages of the DMAIC method found factors that affect defects in low force and high force type products, namely the problem of unstable temperatures. The application of mistake proofing and digitalization with the website is carried out as an improvement for its prevention. The Six Sigma application succeeded in reducing defective products from 2,279 to 2 pcs or increasing sigma from 3.4 to 5.6 sigma
Key words: Six Sigma, Digitalization, Mistake proofing, Quality Improvement

1. INTRODUCTION

The current development of automotive certainly affects the automotive component industry. To meet market needs, the automotive component industry supplies its products to the automotive industry to support its achievement. In Southeast Asia, Indonesia is included in the top-level position in automotive component exports. Indonesia's southeast Asian competitors are Myanmar, Vietnam, and Thailand (Otomotif & Gaikindo, 2019). According to data from Indonesia Automobile Industry Data recorded from year to year the need for exports of Indonesian automotive components always increases, namely in 2019 by 79.3 million, in 2020 by 95.2 million and continue to increase in 2021 by around 97.2 million (Gaikindo, 2021). The automotive components industry exports the most types of chassis and bodies by using molding machine production lines for the manufacture of its products (Jenderal Industri Logam & Transportasi & Elektronika Kementerian Perindustrian, 2018). But in the process the molding machine experienced several obstacles. The most common problem is the unstable mold temperature factor that produces defective products. The main factor in determining the quality of the results of molding machine products is the mold temperature (Ciofu & Mindru, 2013), temperature control which is good at mold can increase the appearance of injection molding process (The Uyen, 2022), Feasibility heating methode can increase melting capability on molding process (Do et al., 2021), Optimization of injection molding temperature parameters reduces shrinkage defects (Kc, B, et al., 2016), Mold temperature not only has a significant influence on print quality results, but also has a direct influence on productivity and cost efficiency (Wang et al., 2014). As for some research there is a car parts manufacturing sector in India using injection molding have a mold temperature problem (Sivaselvam & Gajendran, 2014), then the effect of temperature on automotive products with defects weld line and warpage on injection molding in Malaysia (Nasir et al., 2013). From various mold temperature problems, quality improvement is needed in the molding machine process. In this case, researchers will apply DMAIC and digitalization such as improving quality such as reducing manufacturing conversion costs using quality control tools and digitizing real-time data (Shivajee et al., 2019), The process of measuring DMAIC structures is verified and identified by related technologies and concepts industry 4.0 (Alaloul et al., 2020), Six Sigma 4.0 optimize processes quickly thanks to the rapid DMAIC roadmap on information systems (Arcidiacono & Pieroni, 2018). So that the six sigma approach and digitalization are expected to improve the quality and productivity of the automotive component industry.

2. LITERATURE STUDY

In order to win the market, it is necessary to improve quality in order to be able to compete in the industrial world. Juran argues that quality is a match in the use of products in order to meet customer needs and satisfaction (Juran & De Feo, 2017). Another opinion about quality according to Crosby in (Supriyadi, 2021), quality is conformity with what is required and standardized. As for the opinion of Deming in Puspasari et al (2019), the quality is in accordance with the needs and demands of the market. Quality is a dynamic state that has an influence on products, processes, people, and the environment that exceeds expectations (Atmaja, 2018). Then (Kotler et al. 2015: 224), product quality is a product that has value so that it can trouble consumers both physically and psychologically so that it shows the properties and attributes possessed by the goods. The history *at six sigma* was begun or developed by Bill Smith, as Vice President of Motorola Inc. (Hiroshi Kume, 1989). *Six sigma* is widely known as a methodology that can allow companies to create a quality product quality (Smętkowska & Mrugalska, 2018). Because it can improve productive processes and quality products to meet the needs of consumers or the market (Antony et al. , 2012). Ifa business process is able to compete in the market, the defects of the products produced must not exceed 3.4 per million opportunities if the output has a normal distribution. Empirically *six sigma* is a distribution shift of 1.5σ (Council Six Sigma, 2018). But not all industries and all processes have shifted within the ± 1.5σ. One example in the automotive industry more or less since 1980 has a shift ± 1σ. Currently, the convention can ensure everyone follows the sigma shift of ± 1.5σ. Deviations in long-term processes in a business can be simplified interpretation as a shift in sigma (Rosiani, 2018). In *the Six sigma* methodology, it has a repair process called DMAIC *(Define-Measure -Analyze-Improve-Control)*. This method is a methodology as an approach or application to problem solving in *Six sigma*. DMAIC is used as a continuous improvement of a process or product in a company's business (*The Six Sigma Way*, 2020). To improve a process or product in an existing business, a DMAIC model is needed. The DMAIC stage has a continuity that can form a cycle in each process that is interrelated between one process and another (De Mast & Lokkerbol, 2012). This DMAIC method is the core of the analysis of *six sigma* that can guarantee VOC *(voice of customer)*. From such VOCs produce processes or products that are appropriate and satisfy customers (Carroll, 2013).

In solving this problem, previous research was used as a guide. The following are some previous studies that were used as reference material (Table 1)

Table 1. Research Quotations and Research Position

No	Topic	References
1	A DMAIC approach for process capability improvement an engine crankshaft manufacturing process	(Sharma & Rao, 2014)
2	Defects reduction in steering gear product using six sigma methodology	(Raju et al., 2014)
3	Quality Improvement by using Six Sigma DMAIC in an Industry	(Yadav & Sukhwani, 2016)
4	An application of six sigma for SMEs: A case study	(Kaushik & Kumar, 2017)
5	Reduction of rejection of cylinder blocks in a casting unit: A six sigma DMAIC perspective	(Gandhi et al., 2019)
6	Defect Analysis and Implementation of DMAIC Methodology for Defect Reduction in Tyre Manufacturing	(Ranade, 2019)
7	Six Sigma Methodologies for Increasing the First Pass Rate of Engines in Manufacturing	(Pathmanaban, 2019)
8	Application of DMAIC to Reduce the Rejection Rate of Starter Motor Shaft Assembly in the Automobile Industry: A Case Study	(Sundaramali, 2021)
9	Process Improvement Using Six-Sigma (DMAIC Process) in Bearing Manufacturing Industry: A Case Study	(Bhargava & Gaur, 2021)
10	Lean six-sigma: Panacea to reduce rejection in gear manufacturing industry	(Guleria et al., 2021)
11	Quality Improvement In The Molding Machine Process With Six Sigma Approach And Digitalization In The Automotive Component Industry	Position of thisresearch

3. RESEARCH METHODOLOGY

To reduce defective products in the molding machine process, an activity framework needs to be made as a guide for carrying out repair activities. The research was inspired by previous research using the six sigma method as shown in table 1. The study will follow several steps as a framework to reduce problems that occur in the molding machine process so that it can increase the sigma value. The framework is shown in figure 1.

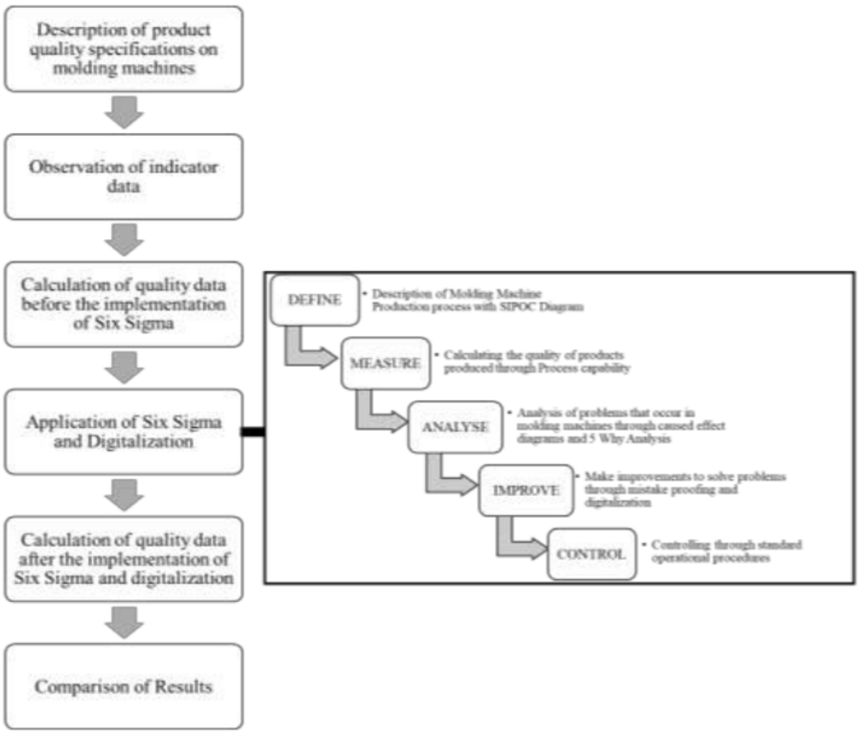

Fig. 1. Research framework

4. RESULTS AND DISCUSSION

4.1 Define

At the definition stage, using SIPOC (Supplier, Input, Process, Output, Customer), which aims to describe the molding machine process that takes place so that it can find the focus of problems that occur in the molding machine process. The SIPOC diagram of the molding machine process that makes the 021#1 keypad product is as follows (Figure 2).

4.2 Measure

This stage of measurement aims to measure the facts that will generate the data, and will be useful as knowledge to improve quality. In this stage, process capability and Defect per Million Opportunities (DPMO) are measured. The measurement data was carried out for one month, namely December 2021 with a 021#1 mold design that runs on a 150-ton injection molding machine of hydraulic type vertical type presented in Table 2.

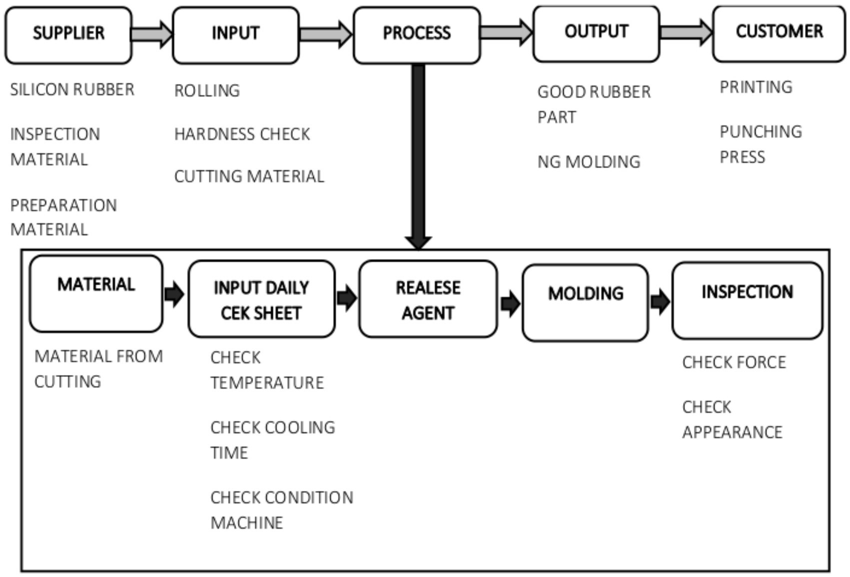

Fig. 2. SIPOC diagram of the molding machine process that makes the product keypad 021#1

Table 2. Mold design force data 021#1 December 2021

Rolling Weekly	Cavity	Sample	Force	Spec LSL	Spec USL	Rolling Weekly	Cavity	Sample	Force	Spec LSL	Spec USL
1	1	1	5.055	4	6	4	9	16	5.111	4	6
	5	2	5.107	4	6		12	17	5.46	4	6
	8	3	5.374	4	6		16	18	5.41	4	6
	9	4	4.985	4	6	5	1	19	5.065	4	6
	12	5	5.25	4	6		5	20	5.291	4	6
	16	6	5.268	4	6		8	21	5.187	4	6
2	1	7	4.929	4	6		9	22	5.109	4	6
	5	8	5.14	4	6		12	23	5.34	4	6
	8	9	5.008	4	6		16	24	5.38	4	6
	9	10	5.134	4	6	6	1	25	5.065	4	6
	12	11	5.213	4	6		5	26	5.291	4	6
	16	12	5.361	4	6		8	27	5.187	4	6
3	1	13	5.075	4	6		9	28	5.105	4	6
	5	14	5.302	4	6		12	29	5.57	4	6
	8	15	5.198	4	6		16	30	5.46	4	6

The measurement of the process capability of making product 021#1 keypad design product is to use minitab 17 software. By entering the data that has been taken from the field into the Minitab 17 software, the results will be seen like Figure 3.

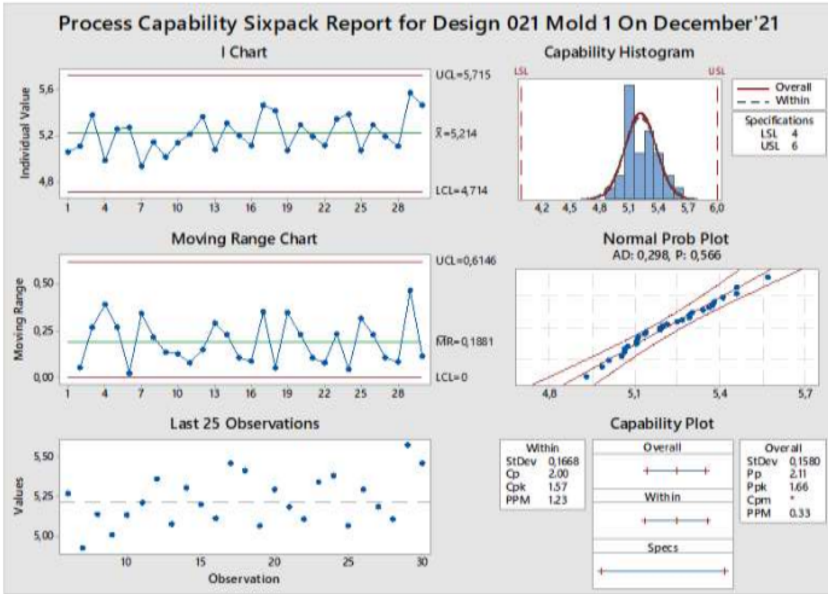

Fig. 3. Process capability of the mold design force data 021#1 in December 2021

From Figure 3, you can see the results of the calculation of process capabilities with values of Cp = 2, Cpk = 1.57, standard deviation of StDev 0.1668, and 1.23 PPM (parts per million). From the description of the assessment of the capability of the design product process 021#1, it can be concluded that the process is very good with a CP above 1.33. After calculating the capability of the process, the next step is to calculate the DPMO to show the sigma level in the process of making the 021#1 design keypad product The calculation stages are as follows:

1.Units (U): The number of 021#1 design products produced in December 2021 is 40,484 units.
2.Opportunities (OP): The critical to quality characteristics specified in this issue are 2 characteristics, yes it is low force and high force defects
3.Defect (D): Low force and high force defects that occurred during the production process of design products 021#1 in December 2021, namely 2,279 defects.
4.Defect Per Unit (DPU) = D / U = 2,279 / 40,484 = 0.00563.
5.Total Opportunities (TOP) = U x OP = 40,484 x 2 = 80,968.
6.Defect Per Opportunities: DPO = D / TOP, DPO = 2,279 / 80,968 = 0.0282.
7.Defect per Million Opportunities: DPMO = DPO x 1000,000, DPMO = 0.0282 x 1000,000 = 28,200. The DPMO value of 28,200 is at the level of 3.4 sigma.

Seeing from the achievement of the sigma level, it is necessary to improve or improve the quality so that the company's target is achieved at a level above 5σ. So that the company is more competitive to achieve its targets.

4.3 Analyze

This stage is a step to determine the main factors causing low force and high force defects in the 021#1 design product that occurred in December 2021 and analyze the various root causes of problems of force defects, in terms of man, method, material, and machine so that the results can find the main factors causing defects and improve the quality of the 021#1 design product manufacturing process. In the analysis stage the researcher used a fishbone diagram. As for the fishbone diagram to find the main factors of the problem in the production process of the molding machine that makes the product design 021#1 as figure 4.

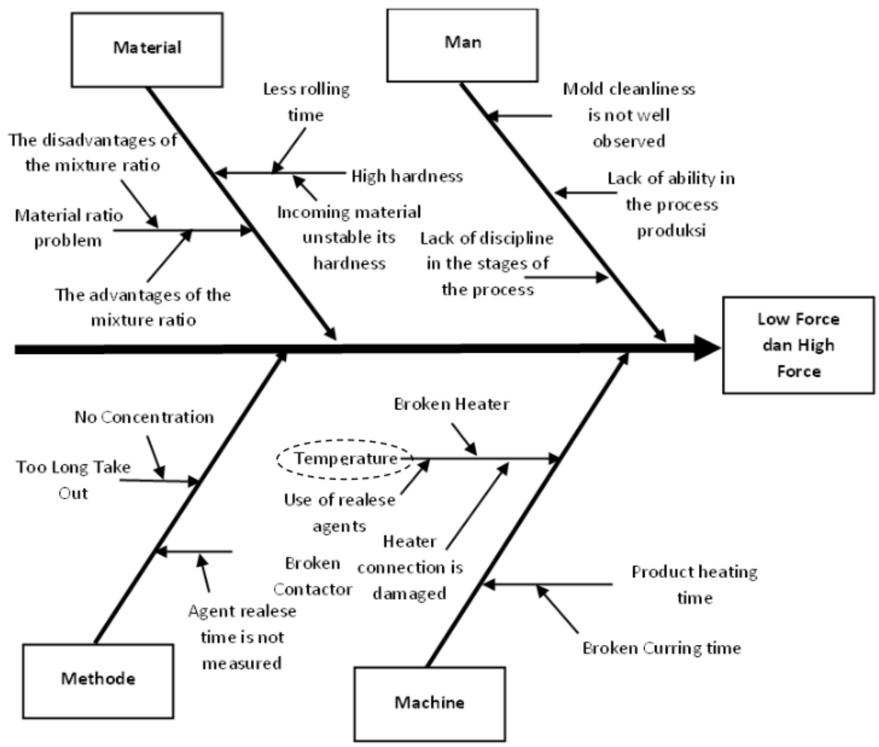

Fig. 4. Fishbone diagram of low force and high force problems on keypad products 021#1

Figure 4 shows several factors that result in the occurrence of low force and high force defects. The explanation is as follows:

1. Man: From the analysis carried out on low force and high force defects, the human factors that affect are the cleanliness of the mold is not considered properly, lack of ability in the production process, lack of discipline to the stages of the production process.
2. Method: For the method factor that affects product defects at the time of manufacturing the product design 02#1 is a method of using unmeasured release agent time so that it can cause mold temperature drops and low force defects occur.
3. Material: In the material phakor that affects the defects of low force and high force products at the time of manufacturing the 021#1 design product is high hardness caused by insufficient rolling time and unstable incoming hardness of the material, as well as material ratio errors that exceed or lack its ratio during the preparation process.
4. Machine: The engine factor that affects low force and high force product defects at the time of manufacturing the 021#1 design product is an unstable temperature due to the heater, heater connection and contactor damaged, the product heating time is less because the timer is damaged.

From the description of the fishbone diagram analysis, this study found an unsolved problem in the 150-ton molding machine process to make a 021#1 design product, namely the problem of temperature instability resulting in low force and high force defects.

4.4 Improve

Mistake proofing is a very effective way of improvement to improve the quality of products or processes to support the application of zero defects. So Mistake proofing can be said to be the prevention of mistakes made by human limitations (Carlson 2017). At the improvement stage, researchers use mistake proofing and digitalization with the help of sensors and connected to the internet to provide real-time information about problems that occur in the molding machine process. The website will be used as a medium for controlling DPMO in each shot. These improvements can properly prevent unstable temperature factors so that the resulting product does not experience low force and high force defects. The stage of correcting mistake proofing and digitalization looks like Figure 5.

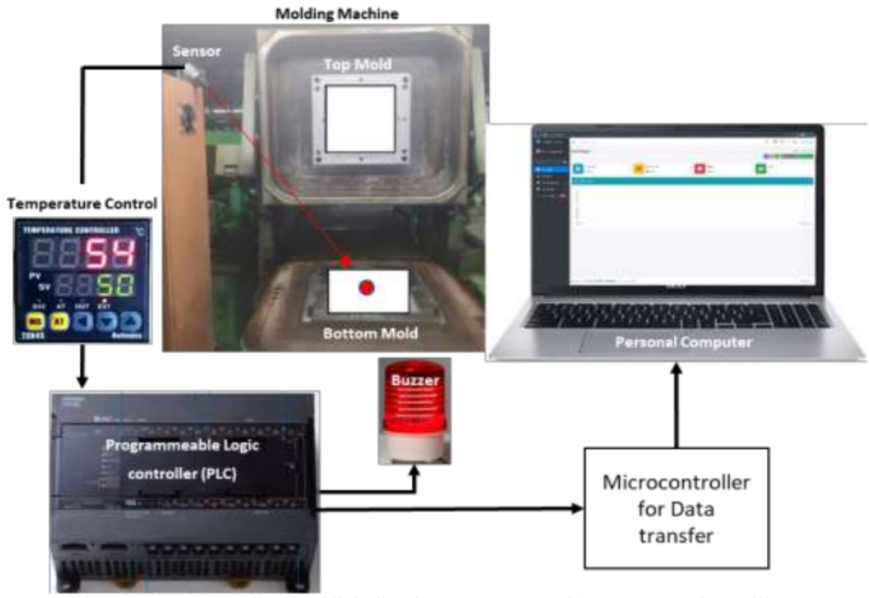

Fig. 5. Mistake proofing and digitalization to prevent mold temperature instability

The way it works from Figure 5 is an infrared type sensor installed to find out the actual temperature of the mold functioning to provide actual information on the temperature of the mold with a display at the temperature control then also provide information to the operator in the form of an alarm system in the event of an abnormality in the temperature of the mold. Information on the abnormality of mold temperature will be informed to the DPMO Website if there is a problem so that it can calculate DPMO in real time on each shot. The temperature specification for the manufacture of 021#1 design keypad products is 170^{o}C ±3. The results of observations of mistake proofing and digitalization that run for 1 month are very effective in controlling mold temperature instability. Proven by the decrease in low force and high force defective products in the 021#1 design keypad product

4.5 Control

The control stage is the last operational step in the six sigma quality improvement program, the improvement will be documented and used as a guideline for the company's work standards. The form of this control stage is documented with instructions for the work process of molding machines or SOPs (Standard Operating Procedures). Standard operating procedures are a guideline, how employees can carry out their work. Therefore, each position in the organization has a different SOP from the same position as the one that is not made, in terms of the control stage that is made is a work guide for the molding machine production process which explains how to run the production process in the molding machine properly so that the resulting product is not defective. The work instructions also explain how the operator's report flows to the production leader if there is an abnormality in mold temperature. So that product defects with low force and high force types can be prevented properly.

4.6 Measuring Process Capability and DPMO after improvement

After carrying out the DMAIC stage for quality improvement on the 021#1 keypad product in the molding machine process, then recalculate the process capability and DPMO (Defect per Million Opportunities) after repair. The goal is to find out the improvement of quality improvements that have been made to the company under study after carrying out the improvement process. The data that will be measured after the improvement is the data for January 2022 (Table 3).

Table 3. Mold design force data 021#1 after product quality improvement in January 2022

Rolling Weekly	Cavity	Sample	Force	Spec LSL	Spec USL	Rolling Weekly	Cavity	Sample	Force	Spec LSL	Spec USL
1	1	1	5.105	4	6	4	9	16	5.109	4	6
	5	2	5.347	4	6		12	17	5.317	4	6
	8	3	5.177	4	6		16	18	5.277	4	6
	9	4	4.996	4	6	5	1	19	5.073	4	6
	12	5	5.291	4	6		5	20	5.251	4	6
	16	6	5.179	4	6		8	21	5.175	4	6
2	1	7	4.998	4	6		9	22	5.112	4	6
	5	8	5.142	4	6		12	23	5.296	4	6
	8	9	5.291	4	6		16	24	5.347	4	6
	9	10	4.989	4	6	6	1	25	5.074	4	6
	12	11	5.198	4	6		5	26	5.256	4	6
	16	12	5.313	4	6		8	27	5.151	4	6
3	1	13	5.055	4	6		9	28	5.107	4	6
	5	14	5.257	4	6		12	29	5.312	4	6
	8	15	5.174	4	6		16	30	5.146	4	6

The measurement after improvement in the molding machine process that makes the 021#1 keypad design product is to use minitab 17 software. By entering data into the Minitab 17 software that has been taken from the field after repairs to the molding machine process, the results will be seen like Figure 6.

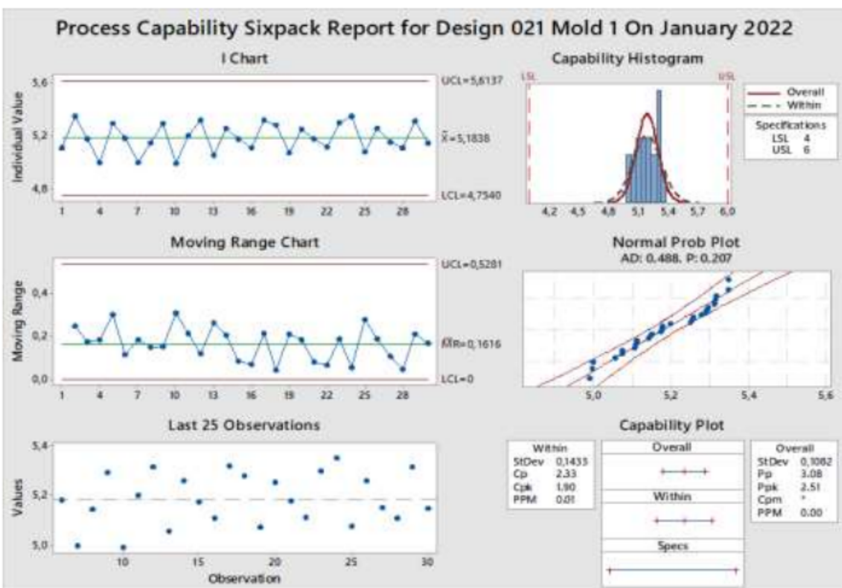

Fig. 6. Process capability after mold design product repair 021#1 January 2022

From Figure 6, you can see the results of the calculation of process capabilities with values of Cp = 2.33, Cpk = 1.90, standard deviation of StDev 0.1433, and 0.01 PPM (parts per million). From the description of the process capability after quality improvement in the 021#1 design product, it can be concluded that the process is very good compared to the capabilities of the previous process, namely with values of Cp = 2, Cpk = 1.57, standard deviation of StDev 0.1668, and 1.23 PPM (parts per million). After calculating the capability of the process, then calculating DPMO after repairs, the guidance is as follows:

1.Unit (U): The number of 021#1 design products produced in January 2022 is 40. 534 units.

2.Opportunities (OP): The critical to quality characteristics specified in this issue are 2 characteristics, yes it is low force and high force defects
3.Defect (D): Low force and high force defects that occurred during the production process of design products 021#1 in January 2022, namely 9 defects.
4.Defect Per Unit (DPU) = D / U = 2 / 40. 534 = 0.000049.
5.Total Opportunities (TOP) = U x OP = 40. 534 x 2 = 81. 068.
6.Defect Per Opportunities (DPO) = D / TOP = 2 / 81. 068 = 0.000025.
7.Defect per Million Opportunities: DPMO = DPO x 1000,000, DPMO = 0.000025 x 1000,000 = 24.5 DPMO The DPMO's N ilai of 24.5 was at 5.6 sigma.

See from the achievement of the sigma level, the company's target has reached a level above 5 sigma. Defective products after improvement and digitalization of the molding machine process that made the 021#1 keypad design product decreased from 2,279 defective products to 2 defective products. It is expected that the company will be able to continue the improvement in order to increase the level of 6 sigma (6σ).

5. CONCLUSION

Research on quality improvement in the molding machine process in the automotive component industry is carried out on the process of a 150-ton hydraulic type vertical type molding machine which makes the product keypad design 021#1 with a six sigma approach and digitalization. From the results of the analysis stage in the DMAIC (Define, Measure, Analyze, Improve, Control) method, several factors that affect the defects of low force and high force types of products, namely man, method, material, and machine. The research focuses on factors that have not been resolved by the company under study, namely the problem of unstable temperatures in the engine by finding quality improvements through the application of mistake proofing and digitalization as an improvement to prevent mold temperature instability. From the application of quality improvement with the six sigma approach, it eliminated the decrease in defective products from 2,279 with a total production of 40,484 to 2 defects with a total production of 40,534 or an increase from the sigma level from 3.4σ to 5.6σ. It is expected that the company will be able to continue the improvement in order to be able to increase to the level of 6 sigma (6σ).

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