JOURNAL OF INDUSTRIAL ENGINEERING & MANAGEMENT RESEARCH
Vol. 1 No. 3 : OCT 2020 ISSN ONLINE : 2722 – 8878
http://www.jiemar.org DOI : https://doi.org/10.7777/jiemar.v1i2

Process Capability Improvement Through DMAIC Method for Aluminium Alloy Wheels Casting

***Edna Maryani*[1], *Humiras Hardi Purba*[2], *Sunadi*[3]**
[1] *Master of Industrial Engineering Program, Mercu Buana University, Jakarta 1650*
[1]ednamaryn@gmail.com
Corresponding author: ednamaryn@gmail.com

Abstract - *High competition in the global wheel market demands is triggering the companies who are produced to improve their process to be able to offer the best wheels quality. Process monitoring charts are employed for improving the process capability index of the process, Some industries set a Cp value greater than 1.33 in assessing their process capability. The aims of this research is to reduce the number of defects in the casting process using the Define Measure Analyze Improve Control (DMAIC) method. It shows the systematic way to find out the major problem root cause at the aluminum castings by using the defect diagnostic approaches and also cause and effect diagram. Other quality tools are used such as the Fishbone diagram and Pareto diagram. These tools identified the major defects for the rejections during production were identified are leaking, porosity hole motive, and oval. In determining the proposed quality improvements using the FMEA tool. The results of data processing on the calculation of process capabilities and product performance show improvements after quality improvements in the casting process.product performance was increased from Cp = 0.81 to Cp = 1.4, sigma level = 2.9 to sigma level = 4.0. The impact for the company is the defect rate was going down and finally it created the production costs saving by IDR 417,550,000 a month. Therefore, the application of the DMAIC method can provide a significant improvement in product quality and giving an impact on production cost savings*
Key words: *process capability, improvement, six sigma, alloy wheel, quality.*

I. INTRODUCTION

Automotive wheels are made of magnesium or aluminum alloy or a mixture of both. Automotive wheels are light wheels that increase the steering and speed of the car because aluminum or magnesium alloys are good heat conductors. Automotive wheels have complex geometry and meet various design criteria such as weight, style, performance, and manufacturing capabilities. In addition, aluminum wheels are corrosion resistant in changing weather conditions, which is a major factor driving the growth of the global automotive alloy wheels market. The Automotive Wheel Market on 2020 can be seen in the following graphic picture:

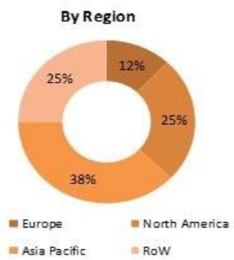

FIGURE 1.1. Global automotive wheel market
Source : *Automotive Wheel Market* (2020)

Based on the Automotive Wheel Market (2020), market demand for world wheel products is by region, namely Europe at 12%, the Asia Pacific at 38%, North America at 25%, and RoW or the rest of the World at 25%. The automotive wheel market began to grow in the Asia Pacific due to the development of the automotive industry and living standards, especially in countries such as Japan, China, and India.

Quality is in accordance with the requirements, the concept of compliance with Crosby requirements describes a set of conditions that must be met in a way required by specifications or standards. In general, if these specifications are not met, the product is considered non-compliant and defective (Juran & Godfrey, 1999). The wheels are made by casting technique, the production process flow consists of three parts, namely foundry process flow, machining process flow, and finishing process flow. The wheel material is heated until melted and then poured into the wheel mold. After that, the finishing is done, which is to clean the rough surface then apply paint. The ability of the process to produce products that meet the specifications if the process has good capabilities, then the process will produce products that are within the specification limits between the lower and upper specification limits (Pyzdek et.al., 2010). Process capability is also defined as the capability of a process to meet its purpose as managed by an organization's management and process definition structures ISO 15504. Two parts of process capability are: Measure the variability of the output of a process, and Compare that variability with a proposed specification or product tolerance(Saravanan & Geetha, 2011). Manufacturing companies will try to increase productivity to be able to compete and compete to get the market to make as much profit as possible with improved product quality and minimize costs incurred (Sunadi et.al., 2020). The Drop Impact Resistance parameter is needed to be improved due to the achievement of the potential capability index (Sunadi et, al., 2020).

The DMAIC (Define-Measure-Analyze-Improve-Control) structured repair procedure is used to solve more complex quality problems and with unknown causes. The Define phase identifying processes or products that need improvement, while the Measurement phase identifies and measures process and product characteristics that are critical to customer satisfaction. The Analysis phase evaluates the operation of the current process to determine the potential source of variation for critical performance parameters. Process improvements are planned and implemented and benefit analysis is done in the Enhancing phase, solutions are documented and monitored through statistical process handling methods in the Operation phase (Aized, 2012). The DMAIC method approach is used in the strategy to achieve process improvement and excellence in enterprise organization, selection of critical parameters as a step to analyze important success factors in improving product quality (Supriyati & Hasbullah, 2020). One method that can be employed as a problem-solving tool to overcome machine breakdowns is the DMAIC approach. DMAIC analysis to support the development of the hot rolling mill machine's capability and elimination of downtime in one of the processes in the aluminum industry (Ashary et.al., 2016). Process control is a solution developed to easily collect and analyze data, allowing performance monitor (Godina et al., 2018).

The control chart combines advanced term chart information with statistical control data to help identify process variations over time that are unlikely due to their random nature. Control charts are very useful in manufacturing, administration, and service functions, control diagrams provide quick feedback on key variables (Montgomery, 2005). Pareto Diagram to stratify potential factors increases nonconforming products (Syafwiratama et al., 2017). FMEA is a systematic analysis of potential failure modes aimed at preventing failures. It is intended to be a preventive action process carried out before implementing new or changes in products or processes (Ford Motor Company, 2011). The long-term goal is to completely eliminate every single failure. The short-term goal is to minimize the failures, if not eliminate them (Stamatis, 2010). Research learning can be done by researching and learning previous research related to the same research, with the object of automotive component research. Six Sigma can be seen as a systematic and organized, customer-oriented methodology that aims to improve the performance and quality of processes, products, and services using statistical techniques and the scientific method to analyze data and make decisions (Costa et al., 2019). The generic problems of alloy wheel machining and subsequently details on the process improvement of the identified critical-to-quality machining characteristic of aluminum alloy wheel machining process (G. V. S. S. Sharma et al., 2018). The intelligent and systematic approach to diagnose the root cause of a potential defects in aluminium castings using quality tools (C. Sharma et al., 2015). The systematic approach to find the root cause of a major defects in aluminium castings using defect diagnostic approach as well as cause and effect diagram (Kumar, 2015).

II. METHOD

The D-M-A-I-C (Define-Measure-Analyze-Improve-Control) structured repair procedure is used to solve more complex quality problems and with unknown causes (Pyzdek, 2003). DMAIC is a closed-loop process that eliminates unproductive steps, often focuses on new measurements, and applies technology for continuous improvement (Smętkowska & Mrugalska, 2018). DMAIC (Six sigma) one of method to used for analyzing defective products and the FMEA method is an option in implementing corrective action in the hope that the process of building a defective product can be properly controlled by the company's schedule (Trimarjoko et al., 2019). The application of FMEA in this analysis of breakdown machine problems was more focused than in the analysis using the Cause and Effect diagrams and Pareto diagram tools only (Rozak et al., 2020). The DMAIC cycle consists of five stages that are connected. The DMAIC steps to solve the quality control problem are as follows:

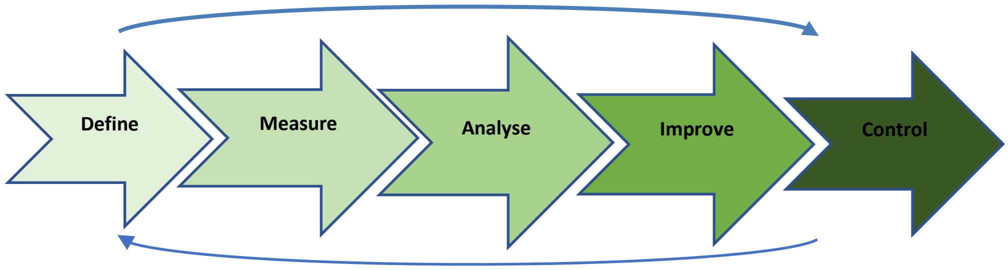

FIGURE 2.1. The DMAIC Process

Define is the phase of determining the problem, determining customer requirements, knowing the CTQ (Critical to Quality). At this stage the implementation team identifies problems, defines customer specifications, and determines goals. Measure is a phase to measure the level of customer disability. The stage for validating problems, measuring / analyzing problems from existing data. Analyze is the phase of analyzing the factors causing the defect. Determining the factors that most influence the process; it means looking for a factor or two that, if corrected, will dramatically improve our process. Improve is the phase of improving the process and eliminating the factors that cause defects. In this stage, ideas for improving our system are discussed based on the results of the previous analysis, doing an experiment to see the results, if it is good, then the standard operating procedure (SOP) is made. Control is the phase of controlling process performance and ensuring defects do not appear. At this stage we have to make plans and measurement designs so that the good results from the team improvement can be sustainable. In this stage we create a kind of metrics to always be monitored and corrected when it starts to decline or to make improvements again (Gazpersz, 2002).

Six Sigma allows to implement scientific methods in the organization to deliver the best value to the customers The Six Sigma method is an approach method to help control the quality of production (Hernadewita et al., 2019). There are also some additional steps that should be taken in DMAIC cycle: observation of important issues of the business and external environment, development of a hypothesis based on this observation, making predictions upon hypothesis, testing the predictions and further observation, conducting experiments and using statistical methods.

JOURNAL OF INDUSTRIAL ENGINEERING & MANAGEMENT RESEARCH
Vol. 1 No. 3 : OCT 2020 ISSN ONLINE : 2722 – 8878
http://www.jiemar.org DOI : https://doi.org/10.7777/jiemar.v1i2

A. Study framework

The Research Methods Framework section is a resource designed to help researchers of all types design a custom research methodology for their particular project. The study framework of this research is as shown in Fig. 2.2:

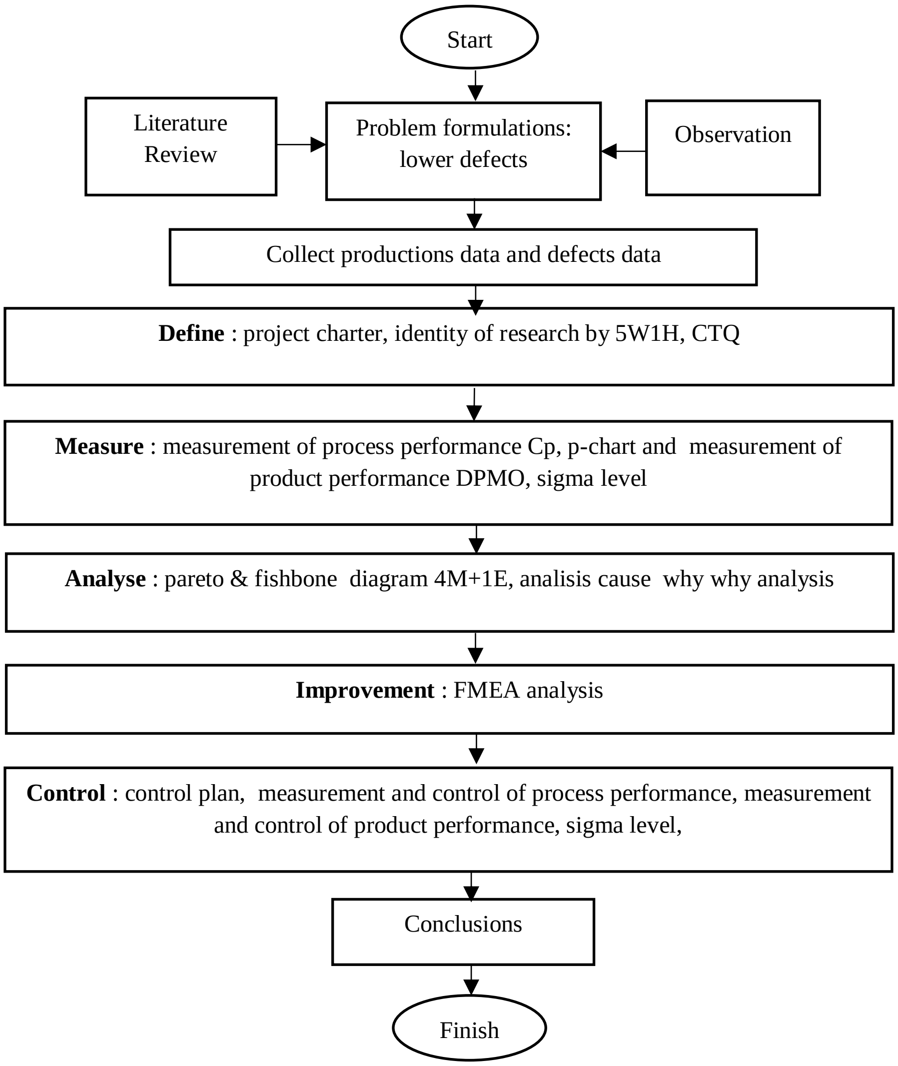

FIGURE 2.2. Study framework

This research started from the formulation of the problem, which is how to reduce the level of defects because it was found that there are many defects on the alloy wheels. The high number of defects exceeds the target, so high rejection results in increased production costs, making it difficult to profit from sales. To correct the shortcomings in the production process, it is necessary to apply the repair method, namely the D-M-A-I-C method.

III. RESULT AND DISCUSSION

In this study, the DMAIC step method (Define, Measure, Analyze, Improve, Control) is used to simplify the repair process, as well as using quality tools as well as calculation and statistical methods at each step.

A. *Define Phase*

The project charter is an influential element of initializing, planning, executing, controlling and surviving the study. The purpose of the project charter is to instigate a Six Sigma project by defining its scope and project variables. States that defect can be defined as any deviation in the performance of the critical to quality (CTQ) characteristics. Each defect explanation as in the following table

TABLE 3.1. Defects Types

No.	Defect types	Description
1	Frontal	Wheel defects if standard front outlet is > +/- 1 mm
2	Porosity hole motive	Small hole defects, wheels offset needle hole area
3	Porosity back spoke	Defects of rear wheelchair area
4	Oval	-Outer lip diameter difference > 1.5 mm -Difference of outer lip thickness Cst-1 > 1 mm and Cst-2 > 1.5 mm
5	Leak	Hole defects in the abdomen of the wheel
6	Balancing	-Difference of outer lip thickness Cst-1 > 1 mm and Cst-2 > 1.5 mm -Top, bottom and centralized inserts -Cst-1 contour thickness difference > 1mm, Cst – 2 > 1.5mm
7	Flatness	Defect rough surface due to die coat process, exposed to dirt
8	Others	If defect handling is found before cutting -Defect mold -Defects that have not entered the criteria above.

Table 3.1. based on the results of field observations and discussions with the Quality Control and Production section, 8 types of defects or Critical to Quality (CTQ) can be determined due to the casting process.

B. *Measure Phase*

Process performance measurement begins with collecting data related to production and total defects on the alloy wheels. Data collection was obtained from production department reports. Here are the actual data to push wheel products in 2019. The percentage of defect casting was 12.37%, while the casting target set by the company was 8%. Production data control chart graph before quality improvement is as follows:

JOURNAL OF INDUSTRIAL ENGINEERING & MANAGEMENT RESEARCH
Vol. 1 No. 3 : OCT 2020 ISSN ONLINE : 2722 – 8878
http://www.jiemar.org DOI : https://doi.org/10.7777/jiemar.v1i2

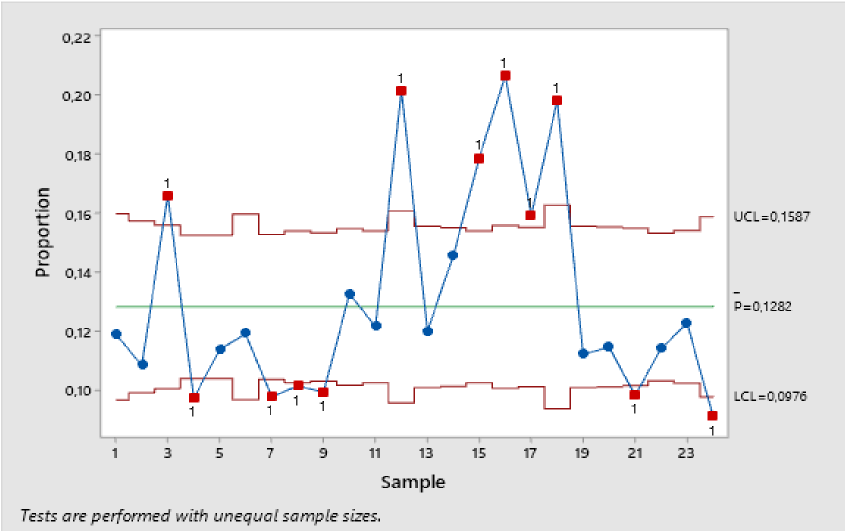

FIGURE 3.1. P-chart of the casting process

In Fig 3.1., the p-chart graph shows that the production process of car wheels is stated to be unstable because 12 points were found to cross the statistical control limit. Process capability (Cp) is calculated based on attribute data, i.e. the ability of the process to produce a suitable or non-defective product in the production process. The graph of process capability before quality improvement is as follows:

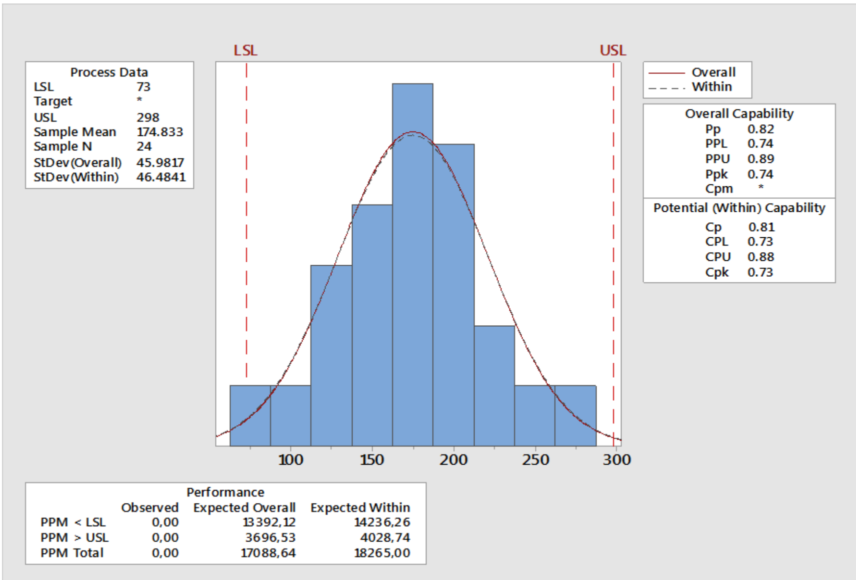

FIGURE 3.2. Process capability

Fig 3.2., measurement of process capability value on process capability in the casting section based on the following attribute data: Cp = 0.81, This indicates that Cp <1.00 the process capability is low. Product performance before improvement: DPMO = 80,031 and the sigma value was 2.9.

C. Analyse Phase

Pareto diagram shows the main problems and the order of priority of some of the most dominant types of defects in the cause of the casting process, as the follows:

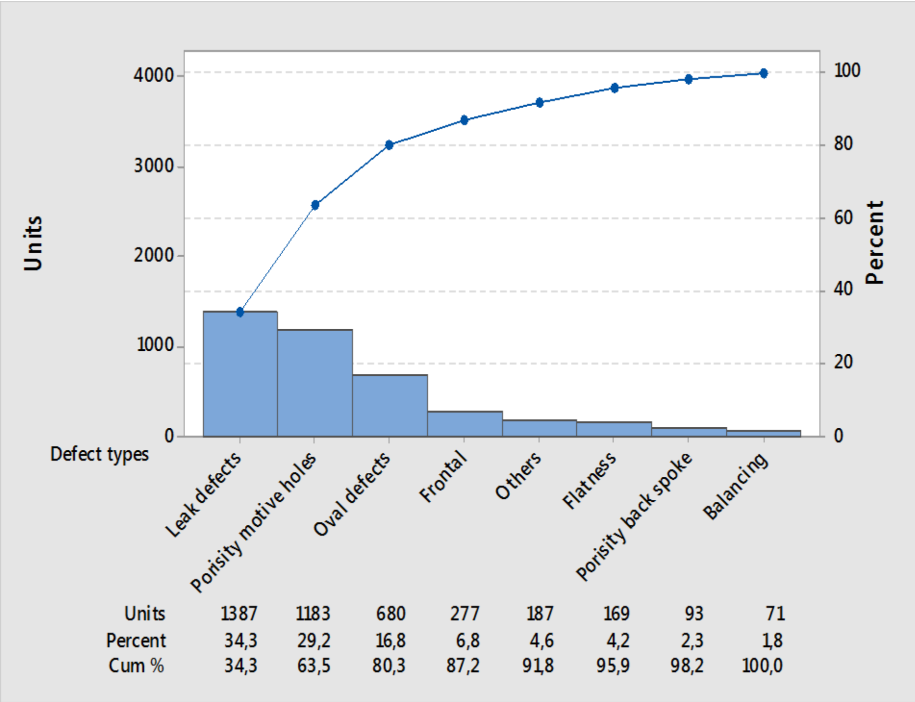

FIGURE 3.3.: Pareto Chart

The highest number of defects occurred in the type of leaky defects as many as 1,387 pcs or 34.3%, porous hole motive as many as 1,183 pcs or 29.2% and oval defects as many as 680 pcs or 16.8% so that the total of the three types of defects became 80.3. %. The type of defect based on the Pareto diagram was analyzed using a fishbone diagram. The root cause of the porous hole motive defect will be found by analyzing the fishbone diagram as follows:

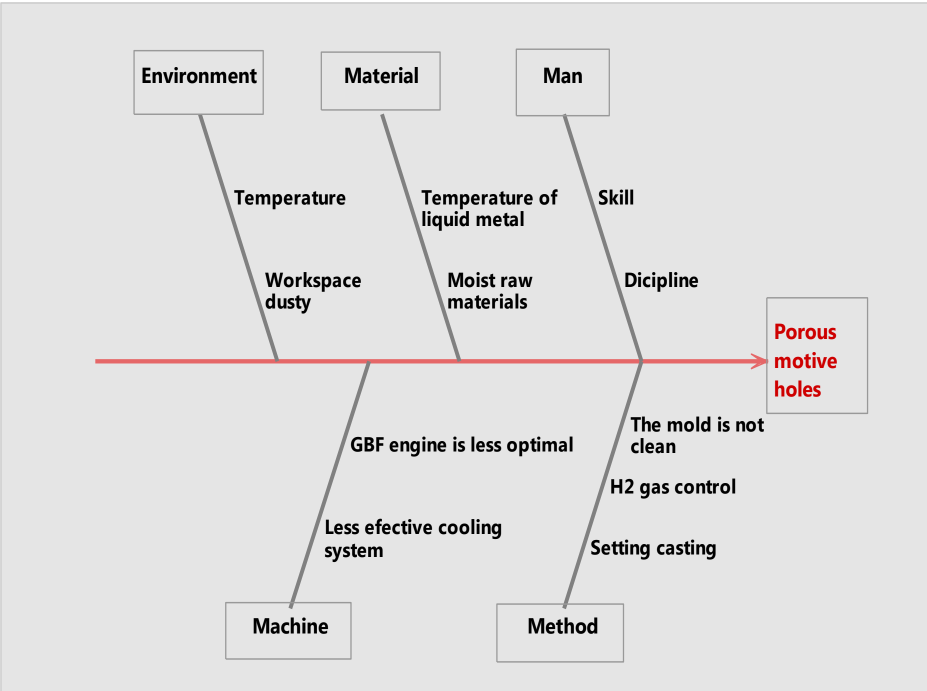

FIGURE 3.4. Fishbone diagram of porous motive holes

In fig 3.4. the human factor is due to the lack of skilled operators, experience and discipline. The engine factor is due to the effectiveness of the cooling system on the lower mold and the degassing tool, the casting machine has not been installed with a water flow meter. The method factor is due to inappropriate cooling system parameter settings and controlling the effectiveness of the degassing unit is not effective. The way to control the hydrogen gas content is not according to the procedure. Cause analysis identifies the root cause or cause of a non-conformity in a process or product. The analysis of the cause of defects with tools of Why Why Analysis, as in the following table:

TABLE 3.2. Cause Analysis Porous Motive Holes

Factor	**Potential fairlure mode**	**Why 1**	**Why 2**	**Why 3**	**Why 4**	**Why 5**
Man	Less skilled	Careless	In a hurry	Lack of experience	Less understanding of assignments	Lack of training & coaching
Machine	The cooling system in the lower mold The GBF engine is less than optimal	Temperature too hot Nitrogen gas flow setting	Temperatur setting N gas bubbles are uneven	The water discharge is not smooth Less control	Less control The rotor is broken	No cooling water regulator The rotor dimensions erode
Method	Less effective control of the degassing unit Control of H2 gas content is less effective	Temperature of the molten metal is too high Peningkatan kadar gas hidrogen	Temperature is not stable Control settings	Less inspection Difficulty controlling H2 gas	Poor rotor condition check The method is not quite right	Control periodically Perlu revisi metode
Material	Temperature of molten metal is not following the standard	Temperature of is too hot	Less control	Less inspection	Less maintenance of kitchen ignition system	Maintenance scheduling not a routine
Environ-ment	Workspace hot and dusty	Casting process area	Near casting machine	Near kitchen ignition system	Temperature is too hot	Radiation from engines

Based on the analysis of the cause, the root causes as human factors, machines, methods, materials and environment are analyzed for the problem and the cause. A large number of mechanical methods and factors. Examples of causal factors such as how to control the degassing device unit is less effective, how to set casting process parameters that do not follow the standards, how to control the H2 gas content is less effective. An example of a causal factor of an engine is a less optimal GBF engine, an optimum cooling system.

D. Improve Phase

In Improve stage, FMEA analysis is carried out to provide suggestions for improvements. From the results of this determination, as shown in the following table:

TABLE 3.3. FMEA Analysis defect casting

Potential failure mode	Potential fairlure mode	S	O	D	RPN	Correction Action
Leak defect	The cooling system is less effective	6	6	6	216	Installation of the cooling water flow meter
Porousity motive holes	The operation of the GBF engine degassing process is not optimal	6	7	5	210	SOP for degassing process control is made
Leak defect	The method of sending samples for x-ray examination is less effective, the samples are not given a production serial number and a stamped mark on the wheel.	6	6	5	180	Each casting wheel is assigned a production serial number and a stamping mark for easy monitoring. A Quality Condition document is produced for training for QC x-ray operators
Porousity motive	Mold cleaning methods are less effective	6	5	5	150	Check the cleaning method with the wind, check the condition of the mold after production in three parts, namely bottom mold, upper core, and die assy
Oval defect	H2 gas control	6	4	6	144	Training and improving work supervision of H2 gas control operators

The main cause of leak defects is that the effectiveness of the cooling system is not optimal (RPN=216) because sometimes the cooling water channel is due to blockage or scale. Also, some machines do not install a water flow meter to regulate the flow rate. The second potential fairlure mode cause of leak defect is the operation of the GBF engine degassing process is not optimal (RPN=210).

E. Control Phase

Efforts to control improvements at the control level with the aim of making no improvements to the process. Corrective action and corrective control were carried out from January to March 2020, so that production quality improvement data were obtained due to casting as shown in the following Pareto diagram:

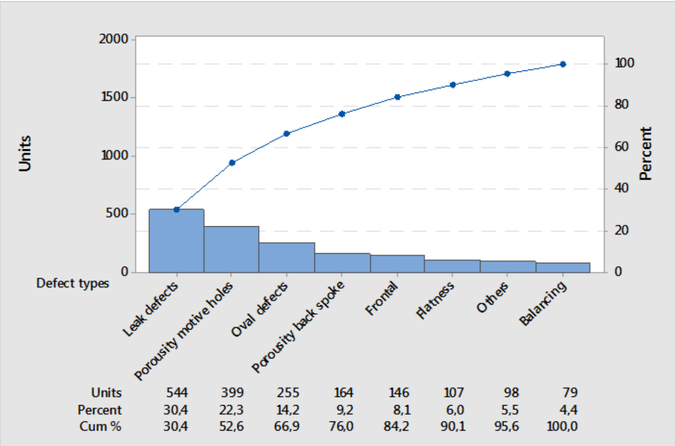

FIGURE 3.5. Pareto Chart of defect types after improvement

Fig 3.5. shows that there is a decrease in the percentage of leaky defects to 32.3%, porous pin / hole motive 23.7% and oval & swaying problem casting 15.1%. P control chart measurements were carried out again in March 2020. Production data control chart charts after quality improvements were made as follows:

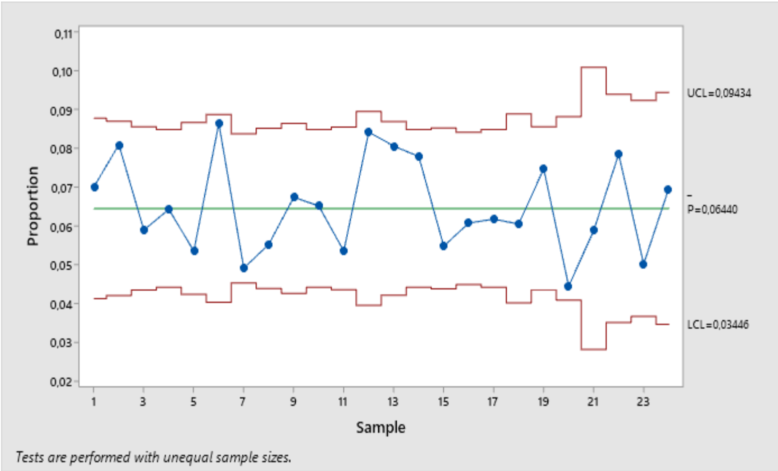

FIGURE 3.6. P-Chart casting process after improvement

Fig 3.6,. shows that no sample points are outside the control line. This indicates that there is an improvement in the wheel production process that is getting better in March 2020. Calculation of process capability is carried out to determine whether the corrective action taken for the process is capable enough.

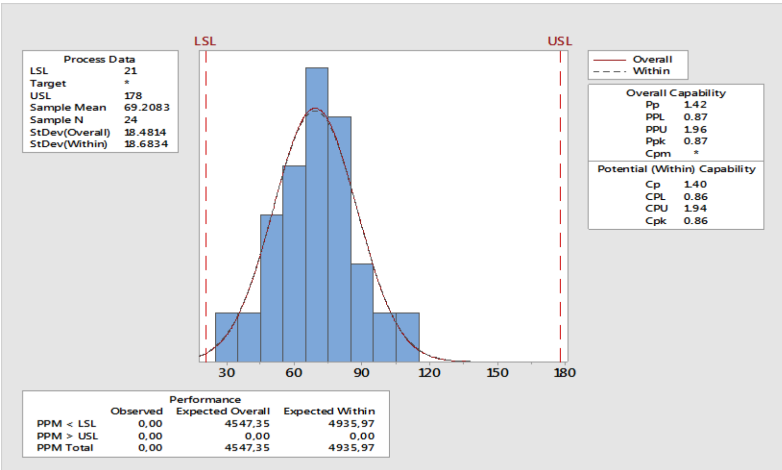

FIGURE 3.7. Process capability after improvement

Fig 3.7. shows that the ability of the process after improvement results in a Cp value of 1.40. If it is seen from the assessment indicator for Cp that Cp > 1.33 then the ability or capability of the process is very good. Product performance after improvement DPMO became 5.164 and the sigma value was 4.0. Calculation of production costs due to a decrease in the percentage of defects, it is known that the production cost per wheel until the casting process is IDR. 175,000. Costs incurred due to inappropriate products are the total costs incurred until the casting process. Before and after improvements based on production and QC report in December 2019 and March 2020 stated that the number of defective products of 4,047 pcs and 1,661 pcs. So the production cost savings are: (4,047 pcs - 1,661 pcs) × IDR 175,000 = IDR. 417,550,000 a month,

IV. CONCLUSSIONS

Based on the findings in the define, measure, analyze and implement improvements in the improve phase and control phase, it can be concluded that the DMAIC method was effective to reduce the defect rate in the casting process. Process performance was increased from Cp = 0.81 to Cp = 1.4 and also the Sigma level is increased from 2.9 to 4.0. The impact for the company is the defect rate was going down and finally it created the production costs saving by IDR 417,550,000 a month. The recommendations for future researchers to make it better is highly in terms of the quality we recommend for combining the DMAIC method with other quality tools like Shainin System and applying it to other automotive component industries.

REFFERENCES

Aized, T. (2012). *Total Quality Management And Six Sigma* (T. Aized (ed.); 1st ed.). In Tech, Janeza Trdine 9, 51000 Rijeka.

Aman, M., & Asbari, M. (2020a). Aplikasi SMS Gateway Berbasis Content Management System Untuk Sistem Informasi Sekolah. *JIKEM: Jurnal Ilmu Komputer, Ekonomi Dan Manajemen*, *1*(1), 1–16.

Aman, M., & Asbari, M. (2020b). Pengembangan Aplikasi History GPS Tracker Berbasis Web Pada Handphone. *JIKEM: Jurnal Ilmu Komputer, Ekonomi Dan Manajemen*, *1*(1), 17–29.

Asbari, M. (2019). Pengaruh kepemimpinan transformasional dan iklim organisasi terhadap kinerja dosen. *JOCE IP*, *13*(2), 172–186.

Ashary, H., & Jaqin, C. (2016). Reducing Downtime Equipment in LPM Machine Line Using DMAIC Approach at an Alloy Wheel Manufacturer in Indonesia. *International Journal of Science and Research (IJSR)*, *5*(7), 740–744. https://doi.org/10.21275/v5i7.art2016205

Costa, J. P., Lopes, I. S., & Brito, J. P. (2019). Six Sigma application for quality improvement of the pin insertion process. *Procedia Manufacturing*, *38*(2), 1592–1599. https://doi.org/10.1016/j.promfg.2020.01.126

Ford Motor Company. (2011). *Failure Mode and Effects Analysis*. Ford Motor Company This.

Gazpersz, V. (2002). *Pedoman Implementasi Program Six Sigma* (V. Gazpersz (ed.); 1st ed.). Gramedia.

Godina, R., Pimentel, C., Silva, F. J. G., & Matias, J. C. O. (2018). Improvement of the Statistical Process Control Certainty in an Automotive Manufacturing Unit. *Procedia Manufacturing*, *17*(6), 729–736. https://doi.org/10.1016/j.promfg.2018.10.123

Hernadewita, H., Ismail, M., Nurdin, M., & Kusumah, L. (2019). Improvement of Magazine Production Quality Using Six Sigma Method : Case Study of a PT . XYZ. *Journal of Applied Research on Industrial Engineering*, *6*(1), 71–79. https://doi.org/10.22105/jarie.2019.159327.1066

Juran, J. M., & Godfrey, A. B. (1999). *Juran's Quality Hanbook* (A. B. Godfrey (ed.); 5th ed.). McGraw-Hill Companies. Inc.

Kumar, E. S. (2015). A Work Study on Minimize the Defect in Aluminium Casting. *International Journal of Emerging Technologies in Engineering Research (IJETER)*, *3*(1), 32–38.

Montgomery, D. C. (2005). *Introduction to Statistical Quality Control* (D. C. Montgomery (ed.); 5th ed.). John Wiley and Sons.

Nuryanti, Y., Novitasari, D., Nugroho, Y. A., Fauji, A., Gazali, & Asbari, M. (2020). Meningkatkan Komitmen Organisasional Dosen: Analisis Pengaruh Kepemimpinan Perguruan Tinggi dan Kepuasan Intrinsik & Ekstrinsik Dosen. *EduPsyCouns: Journal of Education, Psychology and Counseling*, *2*(1), 561–581.

Pyzdek, T. (2003). *The Six Sigma Handbook* (1st ed.). The McGraw-Hill Companies, Inc.

Pyzdek, T., & Keller, P. A. (2010). *The Six Sigma Handbook* (T. Pyzdek (ed.); 3rd ed.). The McGraw-Hill Companies, Inc.

Rozak, A., Jaqin, C., & Hasbullah, H. (2020). Increasing Overall Equipment Effectiveness in Automotive Company Using DMAIC and FMEA Method. *Journal Europeen Des Systemes Automatises*, *53*(1), 55–60.

Saravanan, T. D., & Geetha, D. D. (2011). SPC Tools in Automobile Component to Analyse Inspection Process Associated. *International Journal of Engineering Trends and Technology*, *2*(2), 19–23.

Sharma, C., Bhatia, O. S., & Ucharia, V. (2015). A Quality Approach to Control Casting. *International Journal of Advanced Technology in Engineering and Science*, *3*(6), 42–53.

Sharma, G. V. S. S., Rao, P. S., & Babu, B. S. (2018). Process capability improvement through DMAIC for aluminum alloy wheel machining. *Journal of Industrial Engineering International*, *14*(2), 213–226. https://doi.org/10.1007/s40092-017-0220-z

Smętkowska, M., & Mrugalska, B. (2018). Using Six Sigma DMAIC to improve the quality of the production process : a case study. *Procedia - Social and Behavioral Sciences*, *238*(2), 590–596. https://doi.org/10.1016/j.sbspro.2018.04.039

Stamatis, D. H. (2010). *The OEE Primer: Understanding Overall Equipment Effectiveness, Reliability, and Maintainability* (1st ed.). A Productivity Press Book.

Sudiyono, R. N., Goestjahjanti, F. S., Asbari, M., Fayzhall, M., Yani, A., Winanti, Yuwono, T., Nurasiah, Yulia, Y., Singgih, E., & Chidir, G. (2020). Meningkatkan Komitmen dan Kinerja Dosen : Apa Peran Manajemen Perguruan Tinggi ? *EduPsyCouns: Journal of Education, Psychology and Counseling*, *2*(1), 337–352.

Sunadi, S., Purba, H. H., & Hasibuan, S. (2020). Implementation of Statistical Process Control through PDCA Cycle to Improve Potential Capability Index of Drop Impact Resistance: A Case Study at Aluminum Beverage and Beer Cans Manufacturing Industry in Indonesia. *Quality Innovation Prosperity*, *24*(1), 104. https://doi.org/10.12776/qip.v24i1.1401

Sunadi, S., Purba, H. H., & Saroso, D. S. (2020). *Statistical Process Control (SPC) method to improve the capability process of drop impact resistance : a case study at aluminum cans manufacturing industry in Indonesia* . *7*(March), 92–108. https://doi.org/10.22105/jarie.2020.217565.1135

Supriyati, S., & Hasbullah, H. (2020). Analisis cacat painting komponen automotive dengan pendekatan DMAIC-FMEA. *Operations Excellence: Journal of Applied Industrial Engineering*, *12*(1), 104. https://doi.org/10.22441/oe.2020.v12.i1.009

Syafwiratama, O., Hamsal, M., & Purba, H. H. (2017). Reducing the nonconforming products by using the six sigma method: A case study of a polyester short cut fiber manufacturing in Indonesia. *Management Science Letters*, *7*(3), 153–162. https://doi.org/10.5267/j.msl.2016.12.001

Trimarjoko, A., Saroso, D. S., Purba, H. H., Hasibuan, S., & Aisyah, S. (2019). Integration of nominal group technique, Shainin system and DMAIC methods to reduce defective products: A case study of tire manufacturing industry in Indonesia. *Management Science Letters*, *9*(2), 2421–2432. https://doi.org/10.5267/j.msl.2019.7.013