ANALISIS *LEAN SIX SIGMA* PADA KUALITAS PRODUK SEMEN DI PT SEMEN PADANG (STUDI KASUS: PABRIK INDARUNG III)

LEAN SIX SIGMA ANALYSIS OF CEMENT PRODUCT QUALITY AT PT SEMEN PADANG (CASE STUDY: INDARUNG III PLANT)

Muhammad Chiesa Ade Aditya[1], Ratih Hendayani, S.T., M.M., Ph.D[2]

[1,2]Programme Study of International ICT Business, Faculty of Economics and Business, Telkom University

[1]adityac@student.telkomuniversity.ac.id, [2]ratihendayani@gmail.com

Abstrak

PT Semen Padang adalah salah satu pemain di dalam Industri semen di Indonesia. Di dalam sengitnya kompetisi industri semen dalam negeri, dengan datangnya beberapa perusahaan baru di Indonesia akan membuat industri semen di Indonesia semakin kompetitif. Namun, menurut data *Quality Assurance Factor* PT Semen Padang, masih terdapatnya cacat yang terjadi terkait kualitas pada semen produk PCC PT Semen Padang pada pabrik Indarung III. Penelitian ini bertujuan untuk mengidentifikasi cacat serta proses terkait kualitas yang terjadi pada produk semen PCC di Indarung III dengan metode DMAIC dengan pendekatan *Lean Six Sigma.*

Pada tahap *define*, ditemukan keluhan terkait dengan semen PT Semen Padang, yaitu kuat tekan, dan *setting time*. Pada tahap *measure*, nilai DPMO dari kualitas semen PCC di Indarung III pada bulan Oktober-Desember 2019 adalah 83.089,31186 dengan level sigma 2,89. Tiga *tools* dari six sigma digunakan di tahap *analyze*, yaitu *cause-effect diagram* (*fishbone diagram*), *Statistical Process Control* (SPC), dan *Failure Mode and Effects Analysis* (FMEA). Pada *tools fishbone diagram*, masalah yang terjadi pada pada proses produksi semen berasal dari faktor mesin, manusia, material, dan lingkungan. Pada *tools* SPC, analisis dari proses produksi semen selama Oktober-Desember 2019 diolah menggunakan 4 control chart: $\bar{x}$*-Chart*, *R-Chart*, *p-Chart*, dan *c-Chart*. Pada *tools* FMEA, ditemukan 4 faktor penyebab kegagalan pada proses pembuatan semen.

Berdasarkan hasil penelitian ini, diharapkan perusahaan dapat mengutamakan perbaikan terkait permasalahan yang terjadi pada proses pembuatan semen, terutama proses yang mempengaruhi kualitas, serta melakukan perawatan terhadap mesin yang bermasalah, serta memperhatikan kondisi material yang digunakan untuk membuat semen.

Kata Kunci: *Lean Six Sigma,* Semen Padang, DMAIC, Kualitas, Pengendalian Kualitas

Abstract

PT Semen Padang is one of the players in the cement industry in Indonesia. In the face of fierce competition in the domestic cement industry, the arrival of several new companies in Indonesia will make the cement industry more competitive. However, according to data from PT Semen Padang's Quality Assurance Factor, there are still defects in the quality of PT Semen Padang's PCC cement products in the Indarung III plant. This study aims to identify defects and quality-related processes that occur in PCC cement products in Indarung III using the Lean Six Sigma approach DMAIC.

Complaints regarding PT Semen Padang's cement, namely compressive strength, and time setting, occurred at the defined stage. During the measurement stage, the PCC cement quality DPMO value in Indarung III was 83.089,31186 in October-December 2019 with a sigma level of 2.89. In the analyze stage, three tools from six sigma are used, namely the cause-effect diagrams (fishbone diagrams), the Statistical Process Control (SPC) and the Failure Mode and Effect Analysis (FMEA). The problems that arise in the cement production process in fishbone diagram tools come from the machine, man, materials, and mother nature. In the SPC tools, 4 control charts were used to analyze the cement production process during October-December 2019; $\bar{x}$-Chart, R-Chart, p-Chart, and c-Chart. In FMEA tools, 4 factors have been found to cause failure in the cement manufacturing process.

Based on the results of this study, it is expected that the company will be able to prioritize improvements related to problems that arise in the cement manufacturing process, in particular processes that affect quality, as

well as maintenance of problematic machinery, and to pay attention to the condition of the material used to make cement.

Keywords: Lean Six Sigma, Semen Padang, DMAIC, Quality, Quality Control

1. Introduction

PT Semen Indonesia (Persero) Tbk, which is a state-owned company established by the merging of PT Semen Gresik, PT Semen Padang, PT Semen Tonasa, and Thang Long Cement Vietnam as the domestic market leader [4]. Amid good results in the domestic market, competition is highly intense within the cement industry. Abroad cement producers are boosting competition to a lower level. Cement industry competition remains a problem for PT Semen Indonesia Tbk, where production capacity growth over the rise in national cement demand is the critical cause of long-term high competition in the national cement industry, so capacity figures that are not in line with Indonesia's demand for cement. [5]. Furthermore, the Indonesian Cement Association (ASI) predicts that there will be an increase in demand for cement in Indonesia between 2018 until 2025 [3]. The graph on Indonesia's projected cement demand growth can be seen in figure 1.

Figure 1. Indonesia's Projected Cement Demand

Based on figure 1, the overall capacity of the cement industry in Indonesia will reach 108 million tons in 2018. In this case, the Semen Indonesia Group controls only about 36% of the market. The rest is dominated by foreign and private players who have continued to arise in recent years. Consequently, all competition in the cement industry in Indonesia is very tight. This condition is proved by the participation of the world's big players who are interested in entering the market in Indonesia [7].

To face future opportunities in the cement industry, where players in the cement industry will emerge competition in the cement industry, the existing cement companies in Indonesia need to fight and take the competition in order to enhance customer satisfaction. One way to acquire this is to enhance the quality of current products. Also, companies need to continue developing and improving the quality of products sold to consumers in order to gain a significant market share in the cement industry in Indonesia. However, according to the results of a quality check conducted by the quality assurance unit, there are still problems that occur related to the cement quality at PT Semen Padang. According to Quality Assurance Factor at all the factories in PT Semen Padang, it can be seen that the PCC cement products from Indarung III have many problems compared to other PT Semen Padang Factories [10]. To find out the results of the Quality Assurance Factor at PCC cement product from the Quality Assurance unit at the Indarung III plant in October 2019 to December 2019, it can be seen in table 1, table 2, and table 3.

Table 1. Quality Assurance Factor Result of PCC Cement product at Indarung III in October 2019

FINISH MILL III OCTOBER	PCC CEMENT				
	3D	7D	28D	AW	AK
STANDART	160-210	230-280	320-370	90-180	180-340
S Data	25	24	27	25	25
S In	23	17	18	25	25
% QAF	**92.0**	**70.8**	**66.7**	**100.0**	**100.0**

Average KT & ST	76.5	100.0
QAF TOTAL	**89.93**	

Table 2. Quality Assurance Factor Result of PCC Cement product at Indarung III in November 2019

FINISH MILL III NOVEMBER	PCC CEMENT				
	3D	**7D**	**28D**	**AW**	**AK**
STANDART	160-210	230-280	320-370	90-180	180-340
S Data	30	26	25	30	30
S In	28	17	17	30	30
% QAF	**93.3**	**65.4**	**68.0**	**100.0**	**100.0**
Average KT & ST	75.6			100.0	
QAF TOTAL	**89.53**				

Table 3. Quality Assurance Factor Result of PCC Cement product at Indarung III in December 2019

FINISH MILL III DECEMBER	PCC CEMENT				
	3D	**7D**	**28D**	**AW**	**AK**
STANDART	160-210	230-280	310-360	90-180	180-340
S Data	26	24	30	26	26
S In	23	13	17	26	26
% QAF	**88.5**	**54.2**	**56.7**	**100.0**	**100.0**
Average KT & ST	66.4			100.0	
QAF TOTAL	**85.61**				

The problem of the quality assurance factor at Indarung III is the quality of the cement is under the Internal Standards of PT Semen Padang. It can be seen in the compressive strength on days 7 and 28, both in October, November, and December in 2019 under the internal standard. If the compressive strength of days 7 and 28 has problems, the cement will take longer to reach the desired strength, and the final strength of the cement will be different from the standard cement, which has excellent compressive strength so that the cement will not break easily. In order to know the details that actually occur in Indarung III, additional data are needed to support the data provided by the Quality Assurance Unit. In this case, the quality control unit of PT Semen Padang has responsibility for the quality of the cement at PT Semen Padang as long as the cement is produced. The Quality Control Unit is responsible for controlling the quality of cement during the cement manufacturing process carried out by the Production Unit of PT Semen Padang, while the responsibility of the Quality Assurance Unit is to maintain the quality and problems that occur for the cement that has been released to the market. Therefore, the data from PT Semen Padang's Quality Control Unit will be used in this study to find out more about what happened in October 2019 to December 2019 at the Indarung III plant.

Perceived quality significantly affects corporate reputation. It means that the better its perceived quality, the stronger its reputation [2]. The reputation of PT Semen Padang will, therefore, be influenced by the quality of the cement found in PT Semen Padang. In order to add value to the resulting output, enhancing quality by reducing defects will also decrease inputs and improve efficiency [12]. While the methodology of Six Sigma focuses on decreasing and removing defects in systems and processes, the process methodology is divided into five sequential steps: Define, Measure, Analyze, Improve, and Control (DMAIC). Each step is designed to help an organization make improvements in its business processes [8]. The lean enhancement allows products to flow faster through processes, while Six Sigma enhances the quality and prevents defects by decreasing variety through individual projects. [12]. PT Semen Padang also has the same issue regarding its quality, where the Indarung III of PT Semen Padang plants cannot achieve its internal standard. In this research, the six sigma approach will be aimed to reduce the defect that happened in the cement production process in PT Semen Padang, so later on, the quality will be improved as the defect is already dismissed.

2. Research Literature

2.1 Quality Control in Operation

In Current Organization Business, there are three essential functions that organizations must have: finance, marketing, and operations. That three functions perform in different ways but still supporting each function in the organization [13]. While Operations Management is concerned with converting inputs into outputs that used physical resources to provide the consumer with preferred utilities while meeting other organizational goals of efficiency, effectiveness, and adaptability. There are 8 followings are the activities listed under the functions of Management of Production and Operations, which is the location of facilities, Plant layouts and Material Handling, Product Design, Process Design, Production Planning, and Control, Quality Control, Materials Management, and Maintenance Management. One of the activities listed is quality control, while it is 'the technique of industrial management through which product with an appropriate quality is made.' It is the entire set of activities, ensuring that maximum quality goods are manufactured at a minimum cost [6]. Production quality needs to be the primary focus for businesses, and companies need to manufacture "controlled quality" goods in compliance with corporate standards and requirements set by Local and International Quality Management Areas (ISO). A continuous method of quality control of products is needed in order to achieve a production quality that can stay competitive. Production quality control methods include Total Quality Management (TQM), Statistical Process Control (SPC) and Six Sigma [1].

2.2 Lean Six Sigma

Lean Six Sigma is seeking to merge Lean and Six Sigma's best features. Six Sigma is a structured and systematic methodology for system enhancement and defect prevention. It uses a particular program called DMAIC (Define–Measure– Analyze–Improve–Control) to recognize and reduce waste and achieve excellence [12]. There are 5 steps to conducting Lean Six Sigma.

1. Define
   This stage attempts to explain the production process flow in detail (general system description), describe the company's quality standards, identify the quality attributes that consumers need, and define the forms of waste that exist [9].
2. Measure
   This is a step to gather data on the process's measurable parameters. The goal is to decide what can deliver its sigma to the process in question. During this point, it is better to focus on critical quality parameters, that is, those with the most significant impact on the outcome [14].
3. Analyze
   This step is carried out to generalize the system situations and issues assessed during the measurement stage by identifying and determining the factors affecting the process or technique in the product handling from the beginning to the consumer [9].
4. Improve
   This step investigates different solutions depending on the phase of analysis and prior findings on potential changes to the existing system [9].
5. Control
   This step has a purpose of monitoring the changes that have been made and of examining the progress achieved through the improvements that are expected [9].

3. Result and Analysis of Research

3.1 Define

To do the defined process is determining the voice of customers. Voice of customer data is obtained through customer complaint data that coming in from 2017 to 2019 and obtained through Semen Padang Quality Assurance Unit. The data of complaint as follows in table 4.

Table 4. Complaint Data 2017-2019

No.	Date and Time	Customer's Name	Area	Complaint	Complaint Category
1.	February 3rd, 2017	PT Wika Beton	West Java	Concrete has a water rope when it is dry; segregation occurs, surface water appears when the mixture is allowed to stand for a few minutes at PT Wika Beton	Compressive Strength.
2.	February 4th , 2017	PT Ardi Mix	Lampung	Cement has changed colour, seen in concrete (whiter than usual), and the compressive strength quality has decreased but still above the standard.	Colour, Compressive Strength

3.	February 6th, 2017	PT Waskita Karya Precast	South Sumatera	Precast has a water rope and several small pores and has segregation.	Compressive Strength
4.	March 30th , 2017	PT Merak Jaya Beton	West Java	Cement setting is too fast.	Setting
5.	August 8th, 2017	PT Jutam Ready Mix	Riau Islands	At the time of the slump test, the concrete was seen loosely and not binding.	Compressive Strength
6.	August 9th, 2017	Sindomas Precast	Riau Islands	Precast OPC supplied has decreased quality.	Compressive Strength
7.	December 12th, 2017	PT Remicon Wijaya Prima	Riau Islands	Long setting time due to changing type of cement to PPC.	Setting
8.	February 27th, 2018	PT Sindomas	Riau Islands	The compressive strength of precast has decreased compressive strength.	Compressive Strength
9.	December 12th, 2018	PT Igasar	West Sumatera	Found a lot of broken cement bags when shipping to Mentawai.	Cement Bag
10.	July 18th, 2019	PT Lampung Manunggal Gemilang	Lampung	The initial binding time of cement is above 100 minutes, thus prolonging the production process of precast concrete.	Setting
11.	July 23rd, 2019	PT Batu Ringan Sumatera	Jambi	The difference in the colour of the cement in a mix of concrete in the PT Batu Ringan Sumatera project.	Colour
12.	August 31st, 2019	PT Statika Mitrasarana	Bengkulu	Fragile concrete in a project in the Curup area, Bengkulu.	Compressive Strength
13.	December 12th, 2019	PT Cipto Sadar Pratama (Dira Karya Shop)	Sumatera Barat	The concrete is slow to harden/dry, and the colour is yellow/red cement	Colour, Setting

After knowing customer complaints that occur in the range of 2017-2019, it can be seen that there are three main categories of problems that occur in the cement quality at PT Semen Padang, which the problems related to cement compressive strength, the time setting of cement, the colour of cement, and cement bag. From the results of the complaint, it needs to be translated into a voice of the customer for knowing the key issues, critical requirements, and indicators of what causes the problem, so that PT Semen Padang can more easily interpret what consumers want. The following is a voice to indicator table to turn customer complaints into a core indicator of cement quality problems at PT Semen Padang in table 5.

Table 5. Voice of Indicator from Complaint Data

Voice	Key Issues	Critical Requirement	Indicators
Cement dries in an abnormal time	Wants cement to dry in a reasonable time	Cement dry in normal time according to an internal standard of PT Semen Padang based on the Vicat test tool is 100 minutes minimal, and 300 minutes maximal.	Provides sufficient levels of SO3
Lacking cement quality compressive strength	Wants the excellent quality of compressive strength	Cement has a perfect compressive strength in normal strength based on the compression testing machine. According to the internal standard of PT Semen Padang, the number of compressive strength in 3 days is 180 kg/cm^2 minimal, in 7 days is 260 kg/cm^2 minimal, and in 28 days is 350 kg/cm^2 minimal.	Provides a sufficient level of C3A and C3S. Flime proportion also indicates the perfection of the combustion process, which means the more perfect the combustion process, the better the compressive strength of the cement.
The colour of the cement is abnormal.	Want a standard cement colour.	There are no standards regarding the normal colour of cement at PT Semen Padang, but the composition of the fly ash from cement affects the colour of the cement.	Maximum flyash content of 7%
Broken cement bag	Want to have a good cement bag.	A good cement bag must pass the quality test of a cement bag, where a good cement bag cannot break in the cement bag test experiment, with a minimum test that must pass 80% of the total trial.	Pass the tear resistance test, with a minimum figure of 1123 mN, also pass the tensile resistance test with a minimum number of 3,5 kN/m.

Based on table 5, information was obtained from each problem contained in the customer complaint of PT Semen Padang. Voice of customer data that has been used will be used to determine CTQ (Critical to Quality) for cement quality problems at PT Semen Padang by Pareto Chart in figure 2, and identify the process that conducts in SIPOC diagram in table 6.

Table 6. The SIPOC Diagram of PT Semen Padang

Supplier	Input	Process	Output	Customer
• PT Semen Padang's Limestone Mining site at Karang Putih. • PT Semen Padang's Silica Mining site at Bukit Ngalau. • Iron Sand Procurement from PT Aneka Tambang Cilacap • Gypsum Procurement from PT Petrokimia Gresik, and also imported from Thailand and Bahrain. • Fly Ash Procurement from Limbah PLTU Teluk Sirih • Pozzolan Procurement from Lubuk Alung • Clay Procurement from Kuranji • Coal Procurement from Bangko, Muarolabuh, and Bengkulu Mining Site. • Diesel Fuel Procurement from PT Pertamina.	• Limestone • Silica • Clay • Iron Sand • Gypsum • Coal • Pozzolan • Fly Ash	1. Limestone, Silica, Clay, and Iron Sand is transported from storage to feeder, before entering Raw Mill 2. Each feeder will determine the composition to enter the Raw Mill. The composition is 80% Limestone, 10% Silica, 8% Clay, and 2% Iron Sand. 3. Mixing, Grinding, and Drying Process in Raw Mill 4. Homogenizing the Raw Mix in Homogenizing Silo 5. Burn the Raw Mix into Kiln with 1400 degree Celsius 6. Cooling the Raw Mix in the Kiln, become Clinker. 7. Collecting 3rd Material (Gypsum, Pozzolan, and Fly Ash) and clinker into a feeder that supplies each material. 8. Releasing material from the feeder with the composition is based on what type of cement is produced 9. Mixing and Grinding process in Cement Mill 10. Stored the cement in Silo	• Cement • Clinker	Distributor in Sumatera, Java, and Large party order.

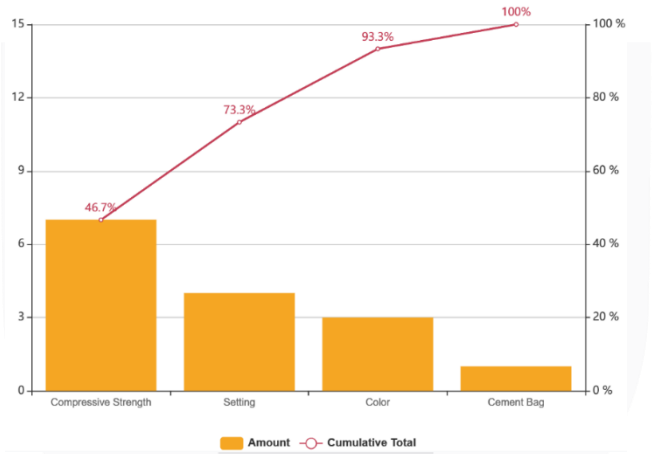

Figure 2. Pareto Chart of Type and Number of Complaint Data PT Semen Padang during 2017-2019

3.2 Measure

At this stage, the defect calculation is done by calculating the DPMO that occurs using the CTQ that has been previously determined, namely the compressive strength and time setting of the cement contained in PT Semen Padang's Indarung III Plant. The number of disabilities that occur every one million opportunities in the cement manufacturing process at PT Semen Padang is **83.089,31186,** which comes from 454 defects found according to the data quality control in Oktober 2019 until December 2019, and 2.732 processes enhanced during that period. Next is finding the sigma of the nearest DPMO. The nearest Sigma from DPMO 83.089,31186 using the Six Sigma conversion table. After that, it was found that the conversion value of DPMO **83.089,31186** was at **2,89 sigma** with yield (success rate of production) is 91.77%.

3.3 Analyze

1. Fishbone Diagram

To identify the main problems with cement quality at PT Semen Padang, each activity is required to map the problems that occur and have a significant impact on the production process and affect the quality of the cement which is then displayed in the Fishbone diagram. On the head of the fish, there will be written a decrease in the quality of cement, which will be followed by six parts of the framework aspect, namely machine, material, man, and mother nature. Method and Measurement were not included because there were no problems with these two aspects. The fishbone diagram for cement quality at PT Semen Padang is in figure 3.

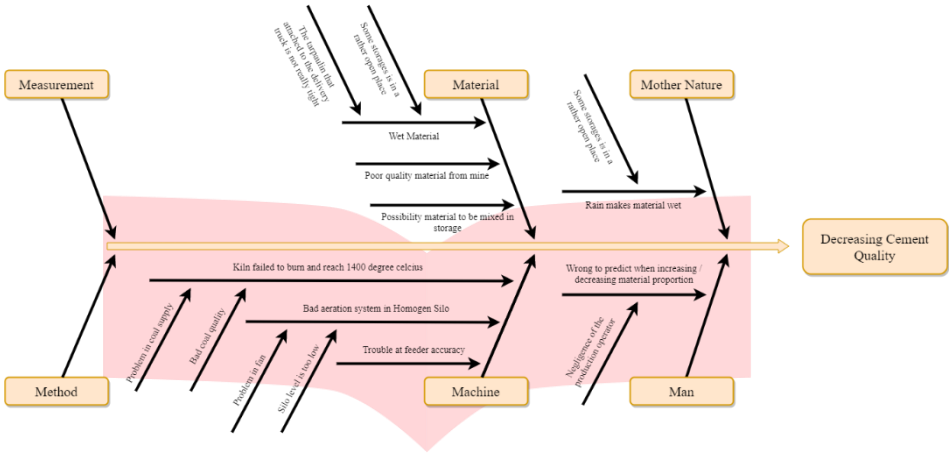

Figure 3. The Fishbone Diagram

2. Statistical Process Control

To monitor and analyze the quality of cement at PT Semen Padang, one of the six sigma tools, which is Statistical Process Control, will be translated into four charts, namely $\bar{x}$-Chart, R-Chart, p-Chart, and c-Chart. All quality calculation processes at this stage will use the POMQM application. The raw data that becomes the input process of the POMQM application are Quality Control Clinker and SO3 data from the Quality Control unit of PT Semen Padang at the Indarung III plant which runs from October 2019 to December 2019 [11], so that each chart displays the results of quality control for three consecutive months. From each month, four materials will be checked for quality, namely Flime (Freelime), C3S, and C3A, as materials that affect the compressive strength of cement, and SO3 which affect the setting time of cement. So, the result will be expanded into 12 chart figures on each chart, and the total overall chart is 48 charts. The 48 charts of SPC can be seen in figure 4, figure 5, figure 6, and figure 7.

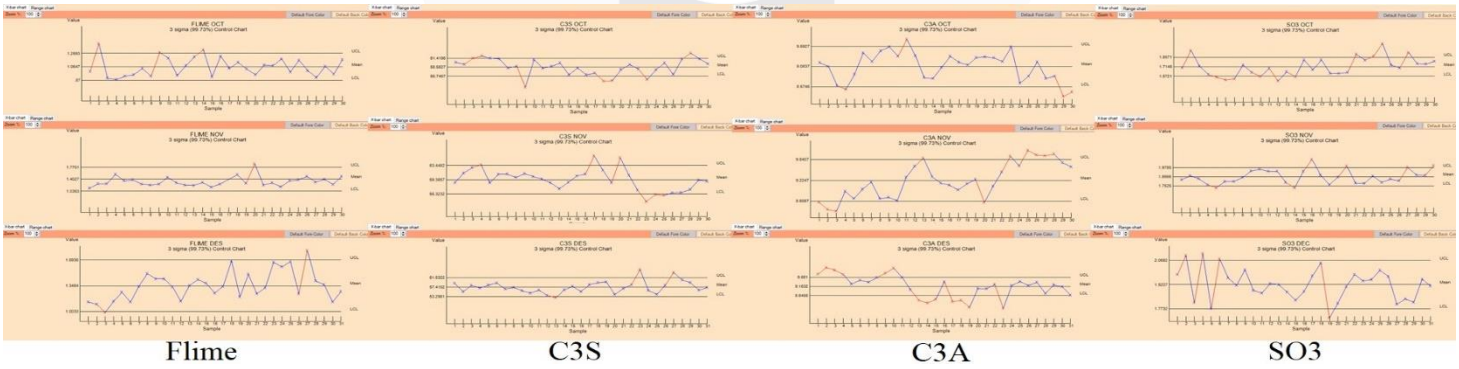

Figure 4. The $\bar{x}$-Chart Result

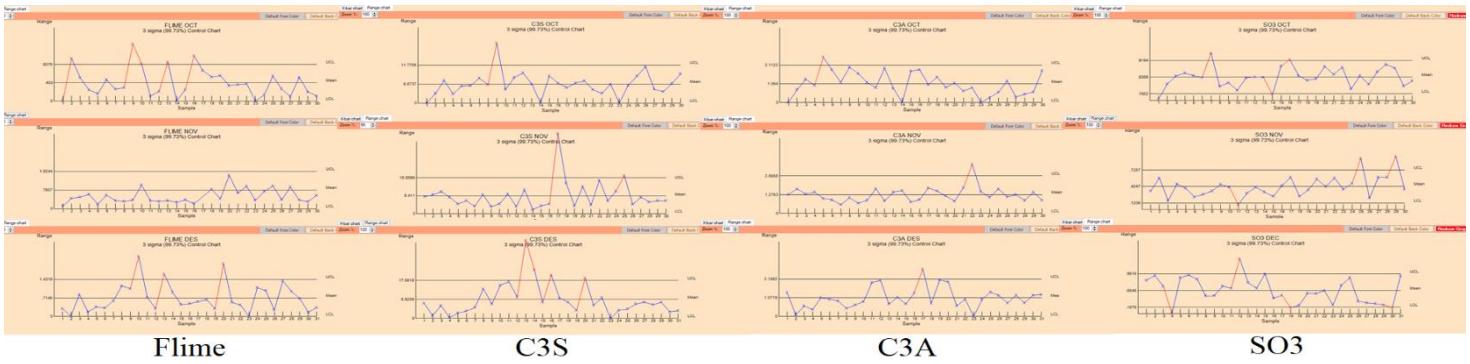

Figure 5. The R-Chart Result

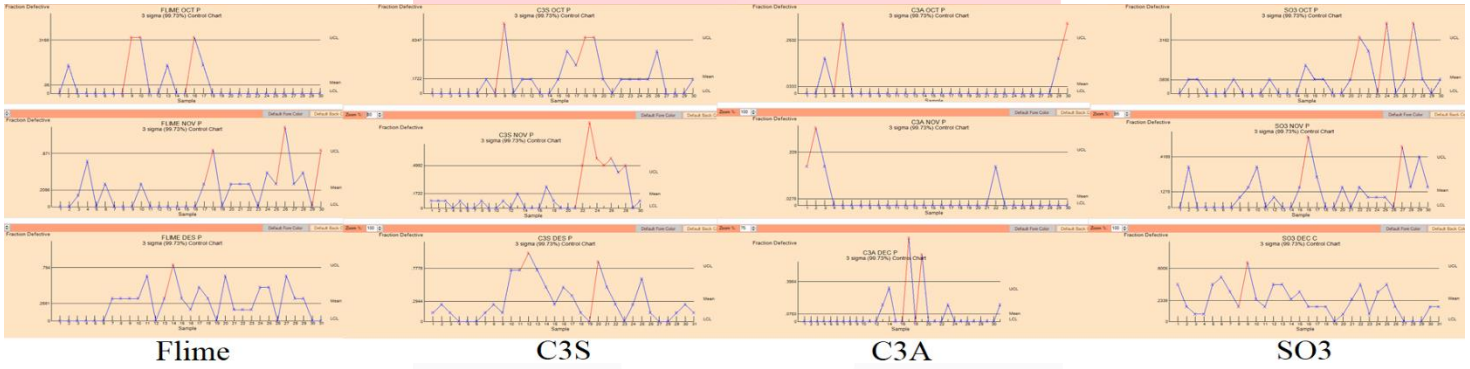

Figure 6. The p-Chart Result

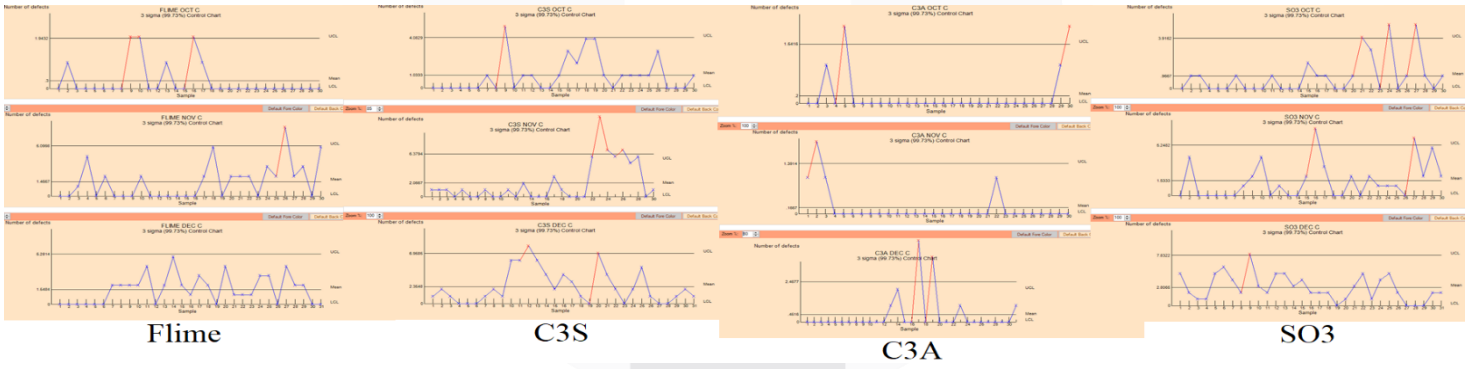

Figure 7. The c-Chart Result

3. Failure Mode and Effect Analysis

At this tools, it is carried out by taking data on the cause and effect of each process, preventing defects, and calculating the severity, occurrence, and detection that occur in the cement production process at PT Semen Padang. In the process of making cement at PT Semen Padang, 4 process steps affect the quality of cement at PT Semen Padang, which is summarized in the FMEA table of the cement manufacturing process at PT Semen Padang in table 7.

Table 7. FMEA Table of the Cement Manufacturing Process at PT Semen Padang

No.	Process Step	Potential Failure Mode	Potential Effects of Failure	Severity	Potential Cause of Failure	Occurrence	Current Controls	Detection	RPN (Severity x Occurrence x Detection)
1.	Grinding material in Raw Mill.	Changes in material quality.	Changes to other ingredients.	7	The quality of material from storage is different from other materials.	8	Tightening the quality control of raw materials supplied from the mine.	3	168
2.	Silos Homogenization.	Failure of the aeration system in the Silo.	The material becomes inhomogeneous and unstable.	8	Silo level is too low, problem in Silo fan.	2	Adding material to the Silo, and repair to the damaged fan.	1	16
3.	Burning the clinker at Kiln.	Failure of the clinker to reach the optimal temperature (1400 degrees Celsius).	The clinker will burn (if it is too high), or the clinker will be uncooked (if it is too low).	10	The quality of coal and the supply of coal.	2	Periodic checking of Kiln.	1	20
4.	Feeding the material from the feeder in the cement mill.	The problem in feeder accuracy.	The cement material will not be precise in its proper composition.	10	Error from feeder engine.	2	Feeder calibration.	2	40

Based on table 7, if ordered from the largest to the smallest RPN, the change in material quality when the material is grinding in the raw mill is a case that has high priority, because the RPN number reaches 168 RPN. The failure of the aeration system in the silo in the silo homogenization process is cases that have low priority, with RPN is 16.

4. Conclusion and Suggestion

4.1 Conclusion

After the authors conducted lean six sigma research on the quality of cement at PT Semen Padang, the following conclusions were obtained as follows.

1. Based on the analysis of the fishbone diagram, it found that the reason why PT Semen Padang has a poor quality product regarding its cement. There are 3 problems and 2 causes of problems from a material point of view, 1 problem and 1 cause from a problem from the perspective of mother nature, 1 problem and 1 cause from a problem from a human point of view, and 3 problems and 4 causes of problems from the machine's point of view. From there, it is known that there are factors that cause problems in PT Semen Padang's cement products, so that the resulting product has decreased quality, and Based on an analysis of Statistical Process Control (SPC) using the POMQM application, some problems occur in the quality of cement when the cement composition data in the range of October 2019 to December 2019 is entered into the $\bar{x}$-Chart, R-Chart, p-Chart, and c-Chart.
2. To look the problem that arises in PT Semen Padang, it used DMAIC process from Lean Six Sigma, with Voice of Customers, SIPOC Diagram, Pareto Chart, and Critical to Quality is used for Define Phase, Measuring DPMO and Sigma level for Measure Phase, and Fishbone diagram, Statistical Process Control, and FMEA Analysis for Analyze Phase.
3. Compressive Strength and Setting Time of cement is the defect that occurred regarding cement quality. Compressive Strength is affected by a large number of incoming clinkers, and setting time is influenced by the amount of SO3 that comes out when gypsum reacts in the Cement Mill.
4. In the DPMO calculation using the 2 CTQs mentioned, it is known that the sigma level at PT Semen Padang at the Indarung III plant is 2.89 in October 2019 to December 2019, with DPMO value is 83.089,31186, It means that the number of defects that arise every one million opportunities in the process

of making cement in Indarung III is 83.089,31186, which is a very big amount of defect for the company such as PT Semen Padang.

5. In FMEA Analysis, PT Semen Padang doing several preventions to reduce the problem. For example, tightening the quality control of raw materials supplied from the mine, adding material to the Silo and repair to the damaged fan, periodic checking of Kiln, and feeder calibration.

References

[1] Didiharyono., Marsal., & Bakhtiar. (2018). Analisis Pengendalian Kualitas Produksi Dengan Metode Six Sigma Pada Industri Air Minum PT Asera Tirta Posidonia, Kota Palopo. *Jurnal Sainsmat*,163-176. Retrieved from Sainsmat.

[2] Hidayat, A., Mahdaria, S., Linando, J. A., & Ishak, A. (2017). The Impact of Perceived Quality and Corporate Reputation Towards Positive Word-Of-Mouth: Trust as Moderating Variable. *Science International*, 29(2), 395-398. Retrieved from Science International.

[3] Indocement. (2018). Paparan Publik PT Indocement Tunggal Prakarsa Tbk 2018. Jakarta: PT Indocement Tunggal Prakarsa Tbk.

[4] Industri, K. (2014, November 27). Semen Indonesia Ada untuk Bangsa Indonesia. Kompasiana [online]. Retrieved from https://www.kompasiana.com/kemandirianindustri/54f3c1b0745513802b6c7f44/semen-indonesia-ada-untuk-bangsa-indonesia [March 27th, 2019],

[5] Investor Daily Indonesia. (2018, January 5th). Semen Indonesia dalam Pusaran Ketatnya Persaingan. Investor Daily [online]. Retrieved from investor.id/archive/semen-indonesia-dalam-pusaran-ketatnya-persaingan [May 12th, 2020].

[6] Mahmoud, Mahmoud Abbas. (2014). Scope of Operations Management. Baghdad: University of Technology Baghdad.

[7] Okefinance. (2017, June 13th). Persaingan Semakin Kompetitif, Semen Indonesia Tambah Kapasitas Produksi. Okezone [online]. Retrieved from investor.id/archive/semen-indonesia-dalam-pusaran-ketatnya-persaingan [May 12th, 2020].

[8] Pisani, M. J., Hayes, R., Kumar, A., & Lepisto, L. (2009). Is Six Sigma culture bound? A conceptual model and propositions for further inquiry. Total Quality Management & Business Excellence, 20(10), 1123–1137. Retrieved from ResearchGate GmbH.

[9] Putri, N. T., Hidayat, B., Yusof, S. M., Fatrias, D., & Indrapriyatna, A. S. (2018). Reducing Bag Defects Using Six Sigma Methodology: A Case Study in A Cement Industry. 2018 7th International Conference on Industrial Technology and Management (ICITM),11-15. Retrieved from IEEE Xplore.

[10] Quality Assurance Unit of PT Semen Padang. (2020). Laporan Quality Assurance Factor Bulan Oktober 2019 – Desember 2019. Padang: PT Semen Padang.

[11] Quality Control Unit of PT Semen Padang. (2020). Laporan Kandungan Klinker Bulan Oktober 2019 – Desember 2019. Padang: PT Semen Padang.

[12] Russell, R. S., & Taylor, B. W. (2009). Operations management: Creating value along the supply chain. Hoboken, NJ: John Wiley & Sons.

[13] Stevenson, W. J. (2001). Operations Management (7th ed.). New York: McGraw-Hill Education.

[14] Youssouf, A., Rachid, C., & Ion, V. (2014). Contribution to the Optimization of Strategy of Maintenance by Lean Six Sigma. Physics Procedia, 55, 512–518. Retrieved from Elsevier Limited.