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BORANG PENGESAHAN STATUS TESIS ◆

JUDUL: **PROCESS CAPABILITY ANALYSIS IN MANUFACTURING TITANIUM DIOXIDE**

SESI PENGAJIAN: 2008/2009

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PROCESS CAPABILITY ANALYSIS IN MANUFACTURING TITANIUM DIOXIDE

NURUL HIDAYAH BINTI RAZAK

This thesis is submitted in partial fulfilment of the requirements
for the award of Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
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6 NOVEMBER 2008

SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurently submitted for award of other degree.

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Dedicated, in thankful appreciation for support,

Encouragement and understanding

To my beloved mum

Wan Rasnah Wan Idris

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ABSTRACT

In this thesis some aspects of process capability analysis are considered. Process capability analysis deals with how to assess the capability of manufacturing processes. Based on the process capability analysis one can determine how the process performs relative to its product requirements or specifications. An important part within process capability analysis is the use of process capability indices. This thesis focuses on process capability analysis in Tioxide (M) Sdn Bhd which is manufacturing titanium dioxide (TiO_2). The objectives of this thesis are to asses the current process capability of the process selected and predict the future capability and identify process improvement opportunities that can be applied in the industry. The process capability was analyzed in four parameters control which are grey stage time, precipitation recovery, crystal size & crystal size distribution and particle size & particle size distribution had been performed in order to predict the future capability of the process. It shows that all the process selected was in capable state, except for Grey Stage Time 1 (GST 1) and Grey Stage Time 2 (GST 2) was incapable and need an improvement. Recommendation had been proposed to overcome this state. Finally, it is hope that this thesis could contribute knowledge for those people who interested in process capability analysis.

ABSTRAK

Thesis ini membentangkan penyelidikan kebolehan sesuatu proses di dalam industri. Kebolehan sesuatu proses itu ditentu dengan kaedah mengakses kebolehan sesuatu proses tersebut. Kebolehan sesuatu proses itu diukur berdasarkan spesifikasi daripada permintaan. Petunjuk atau pengukur sesuatu kebolehan amatlah penting.Thesis ini memfokuskan kebolehan sesuatu proses di dalam menghasilan titanium dioksida di kilang Tioxide (M) Snd Bhd. Objektif thesis ini adalah untuk mengakses kebolehan sesuatu proses semasa dan menganggar kebolehan sesuatu proses itu pada masa hadapan. Selain itu, thesis ini juga bertujuan untuk mencari peluang untuk memperbaik kebolehan sesuatu proses itu. Kebolehan sesuatu proses di analisa berdasarkan parameter tertentu seperti masa pertukaran warna kelabu, proses pemulihan percampuran,saiz zarah cristal & saiz serakkan zarah cristal dan saiz zarah & saiz serakkan zarah. Berdasarkan analisa, semua data menunjukkan kebolehan yang baik, kecuali pada bahagian masa petukaran warna kelabu pada peringkat satu dan dua memberikan keputusan yang tidak memuaskan.Cadangan untuk membaik pulih keadaan ini telah di buat. Segala objektif di dalam thesis ini telah tercapai.Diharapkan thesis ini akan menyumbangkan pengetahuan kepada masyarakat yang ingin mendalami ilmu tentang kebolehan sesuatu proses didalam industri.

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LIST OF SYMBOLS

σ	Sigma
X	Mean
√	Surd
n	No of sample
i	Integer
∑	Summation
Fe	Ferum
Fe_3SO4	Ilmenite
$FeSO_4$	Ferum sulfate
H_2O	Water
H_2SO4	Sulfuric acid
TiO_2	Titanium dioxide

LIST OF ABBREVIATIONS

GST	Grey stage time
LCL	Lower control limit
LSL	Lower specification limit
MR	Moving range
MSU	Milling sand unit
UCL	Upper control limit
USL	Upper specification limit
SPC	Statistical process control

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

In this thesis some aspects of process capability analysis are considered. Process capability analysis deals with how to assess the capability of manufacturing processes. Based on the process capability analysis one can determine how the process performs relative to its product requirements or specifications. An important part within process capability analysis is the use of process capability indices.

This thesis focuses on process capability indices in producing titanium dioxide (TiO_2) at Tioxide (M) Sdn. Bhd, located at Teluk kalung, Kemaman.

1.2 PROJECT OBJECTIVES

The objectives that wanted to achieve in this thesis are to assess the current process capability and predict the future capability of the process to produce product within specification in the company. Another objective is to identify process improvement opportunities that can be applied in the industry

1.3 PROJECT SCOPES

The purpose of the research is to study the process capability analysis in Tioxide (M) Sdn Bhd which is manufacturing titanium dioxide (TiO_2). As a big

manufacturer in chemical industry, Tioxide (M) has moving forward with a mission to improve the whiteness of the pigment and to makes particles of uniform size to improve reflectivity and opacity. In order to hold this target, four parameters have been chosen to be controlled. These four parameters are involving in three stages of process.

1.3.1 Process Stages

There were three stages of process manufacturing titanium dioxide that had been chosen. They are:

A) Precipitation tank
B) Calciner
C) Sand Milling Unit (MSU)

1.3.2 Parameters Control :

In the three stages above, four parameters had decided to choose in order to predict the process capability analysis.

i) Grey Stage Time
ii) Precipitation Recovery
iii) Crystal size & Crystal size distribution
iv) Particle size & Particle size distribution

1.4 BACKGROUND OF TITLE

Process capability is the performance of a process under normal and in control conditions. Its indices are to measure the inherent variability of a process and thus to reflect its performance. To calculate the Cp or Cpk indices for key characteristics, most industries normally assume their process output is normal. The

Cp should be at least 1.33 in order for the process to be considered capable. If the process is not capable, the improvement steps must be taken by the company.

1.5 PROBLEM STATEMENT

This research focuses on the process capability analysis in Tioxide (Malaysia) Sdn Bhd. This factory is the largest manufacturer of titanium dioxide pigments in Malaysia. The titanium dioxide pigments usually use in paints. To accomplish this research, the current process capability was accessed by using data collection and data evaluation. An analyzing had been conducted to predict the future capability by using statistical process control and Minitab had been chosen as software. All the critical parameters stated had been analyzed to make sure the process is in control or out of control.

1.6 METHOD AND PROCEDURES

The methods and the procedures can be seen in section 3.7, while the Gantt Chart of this project schedule is shown in appendix.

1.7 ORGANIZATION OF THESIS

Chapter 1 is about the introduction of the whole thesis. It consists of general introduction that is necessary to understand the process capability analysis concept.

Chapter 2 is the sequences for the chapter 1. It is based on the literature review related to process capability analysis and the titanium dioxide which is the product of the Tioxide (M) Sdn Bhd.

Chapter 3 is about the methodology for this project. This methodology describes the methods and tool used to complete this thesis. It is including how the information gathers, data collection steps, data evaluation process and the software to perform the analysis.

Chapter 4 is mainly about the result and discussion from the analysis. The current state in every process will be present in this chapter. A discussion why does it happen for every graph also will be discussed in this chapter.

Chapter 5 basically is the conclusion and recommendation for the thesis. The whole chapter concluded in this section. Recommendation for future work had been investigated to increase the performance of the process.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter introduces the concept of processes capability analysis and the benefits of implementation it at Tioxide (M) Sdn Bhd, that is classify as a heavy industry in Malaysia. Chapter 2 also discusses the definition of the process capability, the terminology of process capability analysis, capability index, history of titanium dioxide and uses of titanium dioxide in industry.

2.2 DEFINITION OF PROCESS CAPABILITY ANALYSIS

Process capability analysis refers to the ability of a process to produce products or provide services capable of meeting the specifications set by the customer or designer. Process capability gives insight whether or not the process will be able to meet future demands placed on it.

Manufactures of products and providers of services can use process capability concepts to assist in decisions concerning product or process specifications, appropriate production methods, equipment to be used, and time commitment. Montgomery (1996) recommends minimum value for C_p to be 1.33 for existing process and 1.5 for new process. Indeed, a C_p value of 1.33 is commonly used in many industries, as a minimum contractual requirement of process capability expected to from the suppliers. If the process is not capable, the improvement steps or make an enhancement to the process must be taken by the company.

The process capability analysis consists of the sequence used to estimate the process capability, including selecting key quality characteristics, collecting data from the process output and calculating process capability indices. The analysis of process capability has many benefits that contribute to the industry especially in heavy sector. Besides meeting the specifications of the demands, process capability analysis also supplying information on product design and process improvement for engineers and designers. It also provides the basis for reducing the cost of product failures.

In this case study, Tioxide (Malaysia) Sdn Bhd that situated in Teluk kalong had been chosen to collaborate in this research. Tioxide (Malaysia) is actually a global manufacturer and marketer of differentiated and commodity chemicals. Its operating companies manufacture products for a variety of global industries including chemicals, paints and coatings, plastics, automotive, aviation, textiles and footwear,. The scopes of this research involving four parameters those are Grey Stage Time, Precipitation Recovery, Crystal Size & Crystal Size Distribution, Particle Size & Particle Size Distribution.

2.3 PROCESS CAPABILITY ANALYSIS TERMINOLOGY

Process is referring to the combination of men, materials, machines and methods used to manufacture a given product. The process to be studied may be as simple as the control of product purity or as complex as producing a grade of plastic.

Process capability is referring to the normal behavior of a process when operating in a state of statistical control. In manufacturing terminology, process capability refers to the inherent ability of the process turn out consistent product. Process capability may be expressed as percent defective or as distribution. The “capability” of a process is not the same things as its performance, since the performance may include all sorts of unnecessary variables and undesirable disturbances in the cause system. Capability means the natural or undisturbed performance after extraneous influences are eliminated. This is determined by plotting data on control chart.

Process capability analysis is mainly referring to a scientific systematic procedure for determining the capability of the process by means of the control charts, and if necessary changing the process to obtain a better capability. This procedure is continued as long as may be necessary until the problem that prompted the study solved. The term “process capability analysis” implies the solution of problems. They can be applied to almost any problem in engineering, manufacturing, inspection and management.

2.4 PROCESS CAPABILITY INDEX

One of the major problems with many processes is that we demand more of them than they are capable of delivering. Exhorting or punishing the people in the process is particularly futile in such circumstances. Only through full understanding of the process capability in relation to the given specification limits can we determine the real potential of the process.

Given a single specification,for example during manufacturing titanium dioxide (TiO_2). Not all the particles size will exist as the same size and there will be a measurable distribution of particle sizes. If we look at the distribution of particles sizes relative to the lower and upper specification limits, the diagram below show some possible results. We can see that all particle sizes in case (a) will easily be within specification whilst a particle sizes of in (d) will be rejected.

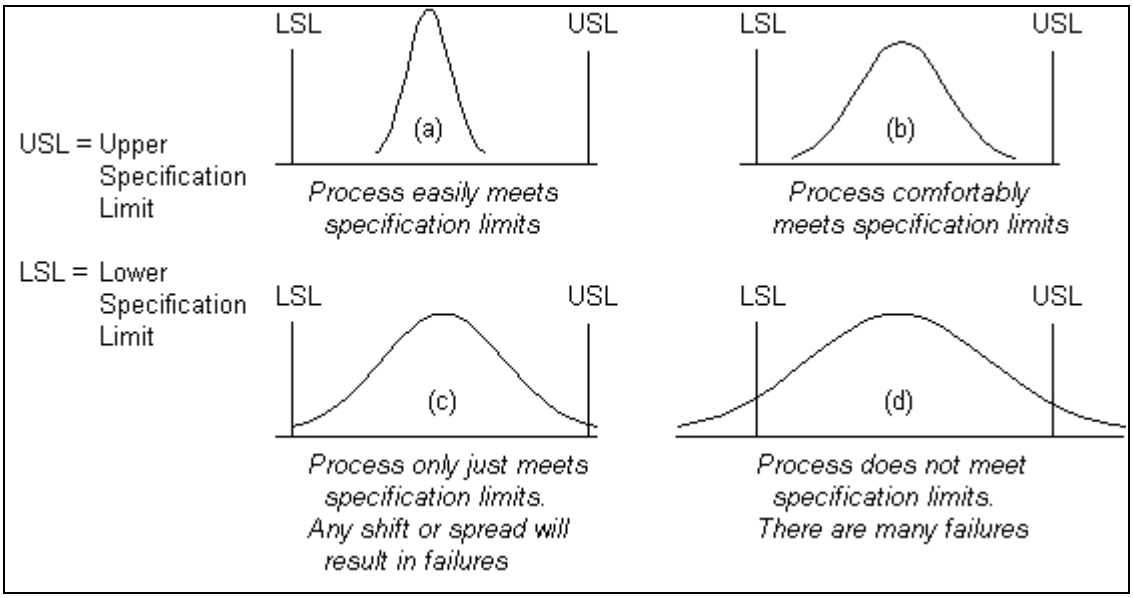


Figure 2.0 Samples of cases in process capability

2.5 CAPABILITY INDICES

The two capability indices are the capability index irrespective of process centering (Cp), and the capability index which accounts for process centering (Cpk). As mentioned above all two of these indices utilize the inherent process variation and thus only take into consideration common cause variation.

2.5.1 Cp Value

The capability index irrespective of process centering or more commonly referred to as the Cp index is defined as the tolerance width divided by the process width. In most cases the process width is taken as six times the inherent variation. Based on the normal distribution, this width represents 99.73% of the population consisting with inherent variation. Since the Cp index is irrespective of centering and includes only the inherent variation. Cp is often referred to as the process potential or in Six Sigma terms, entitlement. Entitlement is this case is the capability that the customer is entitled to.Cp is calculated with the following equation:

$$Cp = (USL - LSL) / 6\sigma \quad (2.1)$$

Cp is the capability index, USL is the upper specification limit, LSL is the lower specification limit and σ is the inherent process variation.

2.5.2 Cpk Value

The capability index which accounts for process centering is referred to as Cpk. Cpk is the most well known of all the indices. Capability analysis is sometimes referred to as Cpk analysis. Cpk is often mistakenly used to represent all types of capability. Because Cpk takes into account process centering it can be used to assess mean deviation (target variation) as well as inherent variation. Cpk is defined as the distance between the average and the closest specification limit divided by half of the process width. Again, in most cases the process width is taken as six times the inherent variation thus half the width would be three times the inherent variation. Many of the industry thresholds used for purchased part approval and process sign-off are based on Cpk values. Cpk is calculated with the following equation:

$$Cpk = (USL - mean)/ 3Sigma \text{ or } (mean - LSL)) / 3\sigma \quad (2.2)$$

2.6 PROCESS TO CALCULATE

This fitting within given limits may be given a numerical value which is known as ‘Cp’. Cp compares the width of the distribution with the width between the specification limits and will thus highlight the problem case (d) in the above diagram. However, cases (b) and (c) are at risk because a slight shift in the average will result in the distribution sliding out of specification on one side or the other. Cp does not capture this, but a modified (and more commonly used) measurement, known as ‘Cpk’, is used to take into account off-centre distributions.

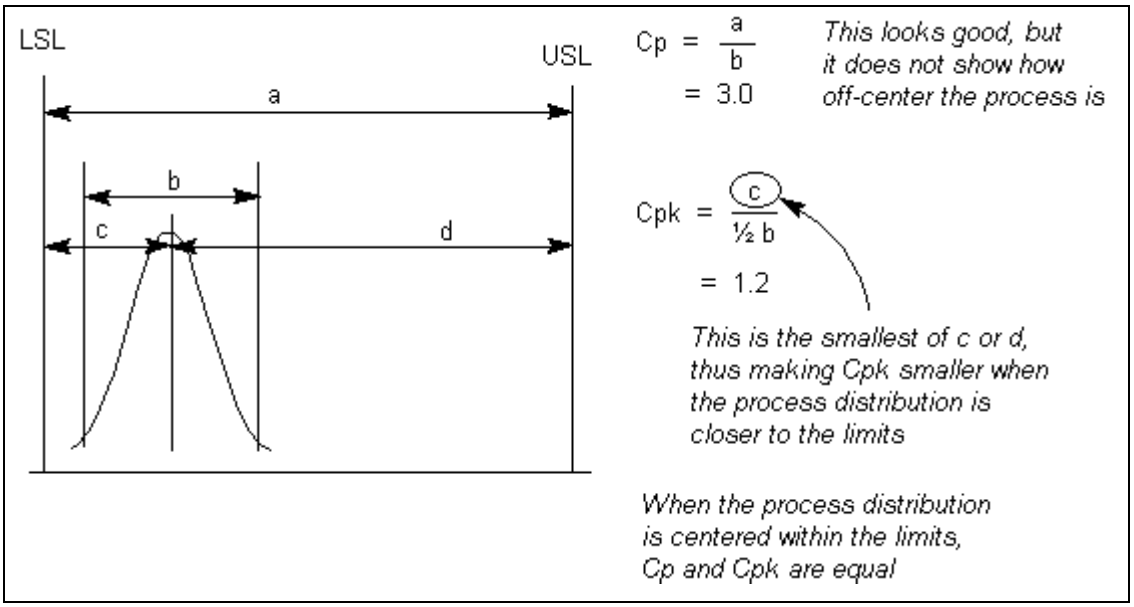


Figure 2.1 Region of Cp and Cpk

2.6.1 Steps To Perform Calculation

1. Identify the process to be measured and the upper and lower specification limits (USL and LSL).

2. Measure the performance of the process under standard working conditions (Note: do not take it off line or measure just after calibration as these optimal conditions will not highlight the true operating capability).

3. Verify that the process is in a state of statistical control with no special causes of variation. This can be done by plotting a Control Chart and looking for trends, shifts, cycles or outliers.

4. Calculate the mean and standard deviation of the distribution of measures.

5. Calculate Cp and/or Cpk as in the diagram below.

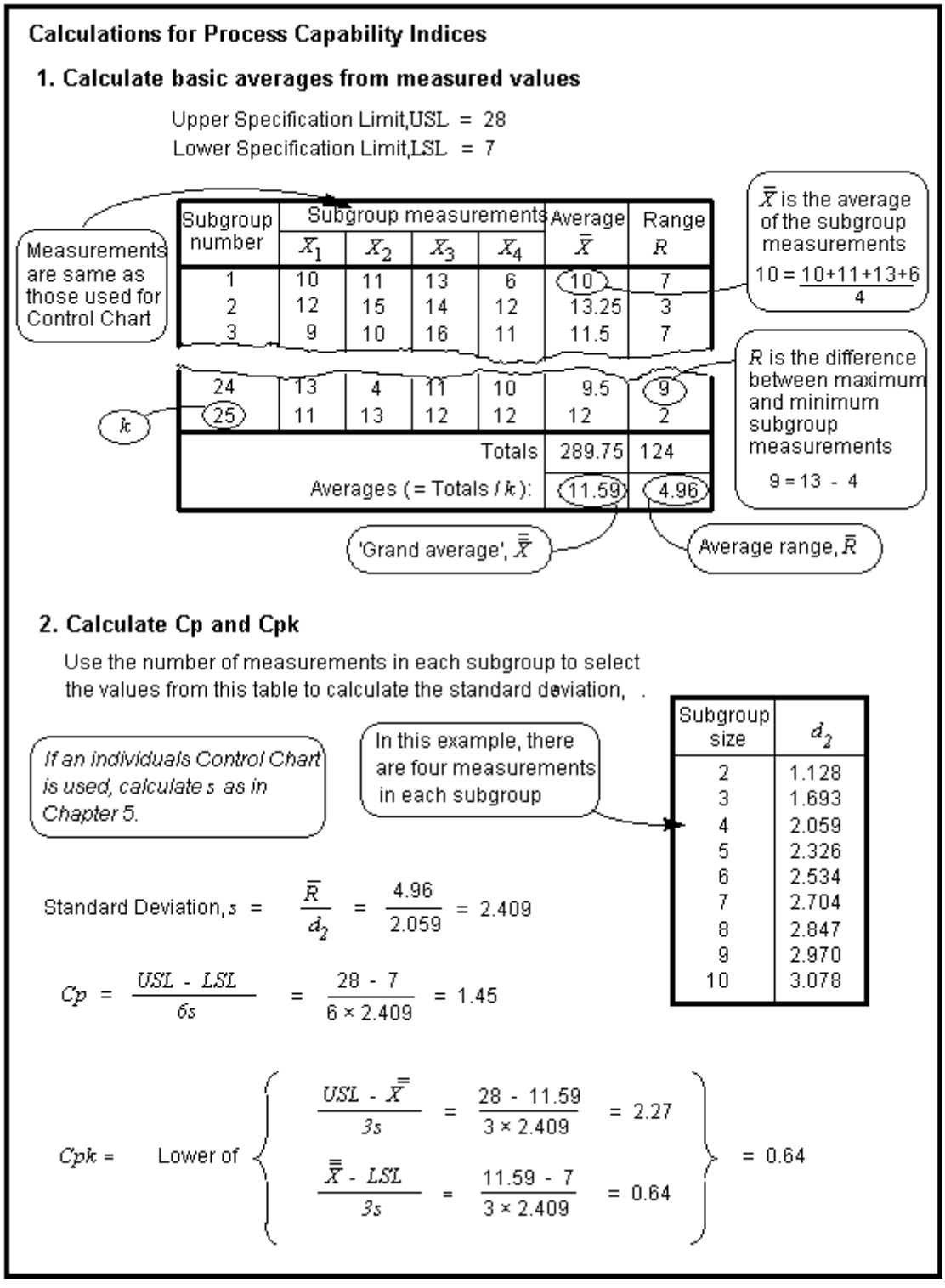


Fig 2.2 Calculation detail for Cp and Cpk

6. The table below may be used to help interpret the final measure and derive consequent improvement action.

Table 2.0 Cpk reference

Value of Cpk	Capability	Action
Less than 1	Incapable	Improve by reducing common causes of variation in process variables. Use 100% inspection.
Between 1 and 3	Capable	Do nothing or some process improvement. Dependent on sample size.
Greater than 3	Very capable	Do nothing or reduce specification limits. No inspection necessary.

2.6.2 Cp References For Industry

In industry, there is a reference of the Cp value to determine the percentage of the process it is in capable or incapable. Below is the table that shows the reference at is measure from the equivalent Cp and the percentage of the capability analysis.

Table 2.1 Cp reference

Equivalent Cp	**Capability, %**
0.50	**86.64**
0.62	**93.50**
0.68	**96.00**

0.81	**98.50**
0.86	**99.00**
1.00	**99.73**
1.33	**99.994**

2.7.0 HISTORY OF TITANIUM DIOXIDE

Titanium was discovered at Creed, Cornwall in England by amateur geologist Reverend William Gregor in 1791. He recognized the presence of a new element in ilmenite, and named it menachite (alternately spelled manaccanite), after the nearby parish of Manaccan [3]. At around the same time, Franz Joseph Muller also produced a similar substance, but could not identify it. The element was independently rediscovered several years later by German chemist Martin Heinrich Klaproth in rutile ore. Klaproth confirmed it as a new element and in 1795 he named it for the Titans of Greek mythology.

The metal has always been difficult to extract from its various ores. Pure metallic titanium (99.9%) was first prepared in 1910 by Matthew A. Hunter by heating $TiCl_4$ with sodium in a steel bomb at 700-800 °C in the Hunter process. Titanium metal was not used outside the laboratory until 1946 when William Justin Kroll proved that titanium could be commercially produced by reducing titanium tetrachloride with magnesium in the Kroll process which is the method still used today.

In 1950-1960s the Soviet Union attempted to corner the world titanium market as a tactic in the Cold War to prevent the American military from utilizing it. In spite of these efforts, the U.S. obtained large quantities of titanium when a European company set up a front for the U.S. foreign intelligence agencies to purchase it. Indeed, titanium for the highly successful U.S. SR-71 reconnaissance aircraft was acquired from the Soviet Union at the height of the Cold War.

Titanium dioxide was first produced commercially in 1923 and accounts for approximately 70% of the total volume of pigment production. Relatively small quantities of titanium dioxide are used for non-pigmentary purposes. In 2004, worldwide production of titanium dioxide was 4.4 million tonnes.

Titanium dioxide is obtained from a variety of ores that contain ilmenite, rutile, anatase and leucoxene, which are mined from deposits located throughout the world. Most titanium dioxide pigment is produced from titanium mineral concentrates by the chloride or sulfate process, either as the rutile or the anatase form.

2.7.1 Parameters Selection.

In order to accomplish the objective of the thesis, some parameters had been stated. Those are, Grey Stage Time (GST) , Precipitation Recovery, Crystal Size & Crystal Size Distribution, Particle Size & Particle Size Distribution. This selection of those parameters follows the objective of the Tioxide that are to reduce the level of impurities in Ferum to improve whiteness, and to make particles of uniform size in order to improve reflectivity and opacity.

2.7.2 Composition Of Titanium Dioxide

Titanium dioxide consists essentially of pure titanium dioxide which may be coated with small amounts of alumina and/or silica to improve the technological properties of the product. It is manufactured by digesting ilmenite ($FeTiO_3$) or ilmenite and titanium slag with sulfuric acid and the product is diluted with water or dilute acid. The resulting liquor is clarified by sedimentation to remove insoluble residues such as silica and iron is removed by crystallization (as FeSO4. $7H_2O$) and filtration. The liquid is then hydrolyzed with alkali under controlled conditions to produce a precipitate of titanium dioxide. The product is filtered, washed, calcined and micronized.

Titanium is a chemical element in the periodic table that has the symbol Ti and atomic number 22. It is a light, strong, lustrous, corrosion-resistant (including resistance to sea water and chlorine) transition metal with a white-silvery-metallic colour. Titanium is used in strong light-weight alloys (most notably with iron and aluminium), and in powdered form to other materials, such as graphite composites. Its most common compound, titanium dioxide, is used in white pigments. Examples, in which white pigment, consisting of titanium oxide, is used, are correction fluid and commonly used white paint to repaint walls. It is also used in toothpaste, white road marking paints and in white fireworks. Substances containing titanium are called titaniferous.

2.7.3 Method to Produce Titanium Dioxide

In industry, there are two method used to produced titanium dioxide. They are sulfate method and chlorine method. The sulfate or Mecklenburg process is used in Tioxide plant.

2.7.4 The Sulfate Process History

The sulfate was the first commercial scale technology used to convert ilmenite to titanium dioxide. Producing large quantities of waste iron sulfate and producing an inferior product for most applications, few sulfate process plants are now being built. In 1996, Tioxide, a sulfate-based plant at Burnie, Tasmania, ceased operation after some forty years in operation using ilmenite shipped from Western Australia and local sulfuric acid from metal smelting operations in Tasmania. The plant produced large volumes of iron sulfate waste product. The sulfate process produces a form of pigment called anatase, which is preferred over chloride-derived pigment for use on papers, ceramics and inks.

2.7.5 Sulfate (Mecklenburg) Process In Manufacturing Titanium Dioxide

The main precipitator receives a suspension of seed particles formed in a separate nucleation tank. These seeds contain rutile and anatase, the letter promoting

reaction of titanium dioxide (TiO_2) from aqueous $TiOSO_4$ to form a precipitate containing mostly anatase but enough rutile to act as seed for rutile formation in the kiln.The overall precipitation in the precipitator is :

$TiOSO_4$ (aq) + H_2SO_4 → TiO_2 ($_S$) + H_2SO_4 (endothermic)

2.8 General Characteristic Of Titanium Dioxide

About 95% of titanium production is consumed in the form of titanium dioxide (TiO_2), an intensely white permanent pigment with good covering power in paints, paper, toothpaste, and plastics. Paints made with titanium dioxide are excellent reflectors of infrared radiation and are therefore used extensively by astronomers and in exterior paints.

The titanium dioxide (TiO_2) provides the opaqueness or opacity of the fil by interacting with the light via a scattering process as it passes through the film. Each particle of TiO_2 diverts some of the light from the original path into new direction within the film. Titanium dioxide has three crystal forms, anatase, rutile and brookite. Rutile is favoured because it has the highest refractive index and hence highest potential light scattering efficiency. Anatase finds favour in system which demands very ‘clean’ whiteness, rutile whiteness being very slightly comprised by a small amount of light absorption at the blue end of the visible spectrum.

Titanium dioxide is well known for its excellent resistance to corrosion; it is almost as resistant as platinum, being able to withstand attack by acids, moist chlorine gas, and by common salt solutions. Pure titanium is not soluble in water but is soluble in concentrated acids. A metallic element, it is also well-known for its high strength-to-weight ratio. It is a light, strong metal with low density that, when pure, is quite ductile (especially in an oxygen-free environment), easy to work, lustrous, and metallic-white in colour. The relatively high melting point of this element makes it useful as a refractory metal. Commercially pure grades of titanium have an ultimate tensile strength equal to that of high strength low alloy steels, but are 43% lighter. Titanium is 60% heavier than aluminium, but more than twice as strong as

6061-T6 aluminium alloy; these numbers can vary quite substantially due to different alloy compositions and processing variables.

This metal forms a passive and protective oxide coating (leading to corrosion-resistance) when exposed to elevated temperatures in air but at room temperatures it resists tarnishing. The metal, which burns when heated in air 610 °C or higher (forming titanium dioxide) is also one of the few elements that burns in pure nitrogen gas (it burns at 800 °C and forms titanium nitride). Titanium is resistant to dilute sulfuric and hydrochloric acid, along with chlorine gas, chloride solutions, and most organic acids. It is paramagnetic (weakly attracted to magnets) and has a very low electrical resistively and thermal conductivity.

Recently, it has been put to use in air purifiers (as a filter coating) or in window film on buildings which when exposed to UV light (either solar or man-made) and moisture content in the air converts unfiltered air pollution into hydroxyl radicals. TiO_2 powder is chemically inert, resists fading in sunlight, and is very opaque: this allows it to impart a pure and brilliant white colour to the brown or gray chemicals that form the majority of household plastics. In nature, this compound is found in the minerals anatase, brookite, and rutile.

2.9 Application In Industry

Titanium dioxide that is produce in Tioxide (M) Sdn Bhd mostly use in paints is primarily to whitened and opacity polymeric binder system (opacity or hiding power). Titanium dioxide pigments in paints also help the durability in usage. There are two types of paints using the concept of opacity and reflectivity. Those are gloss paint and emulsion paint.

Besides that, this white pigment use in printing ink. It is use the essentially same principles govern the performance of titanium dioxide pigment in printing inks as in paint systems.

Because of its high tensile strength (even at high temperatures), light weight, extraordinary corrosion resistance, and ability to withstand extreme temperatures, titanium alloys are used in aircraft, armour plating, naval ships, spacecraft and missiles. It is used in steel alloys to reduce grain size and as a deoxidizer, and in stainless steel to reduce carbon content. Titanium is often alloyed with aluminum (to refine grain size), vanadium, copper (to harden), iron, manganese, molybdenum and with other metals.

Welded titanium pipe is used in the chemical industry for its corrosion resistance and is seeing growing use in petroleum drilling, especially offshore, for its strength, light weight and corrosion resistance.

Use of titanium in consumer products such as tennis rackets, golf clubs, bicycles, laboratory equipment, wristwatches, wedding bands, and laptop computers is becoming more common.

The element occurs in numerous minerals with the main sources being rutile and ilmenite, which are widely distributed over the Earth. There are two allotropic forms and five naturally occurring isotopes of this element; 46Ti through 50Ti with 48Ti being the most abundant (73.8%). One of titanium's most notable characteristics is that it is as strong as steel but is only 60% its density. Titanium's properties are chemically and physically similar to zirconium.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

Chapter 3 is based on the methodology that related to this project. Methodology is a frame work that plays important role in this thesis. A frame work is a planning that has been drafted in order to get the expected results. It is included literature review, data collection, data evaluation, discussion and conclusion.

3.2 LITERATURE REVIEW

3.2.1 Discussion with Engineer at Tioxide (M) Sdn Bhd.

According to project's scope, this thesis related to chemical industry and involving so many process to produce final product of titanium dioxide (TiO_2). So, a few meeting had been arranged with the engineers to give more clearly about how the process running and the critical parameter that was used to control.

3.3 DATA COLLECTION

The data collection is based on the critical parameters that been stated. They are four parameters such as Grey Stage Time (GST), Precipitation Recovery, Crystal Size & Crystal Size Distribution and Particle Size & Particle Size Distribution. All the parameters was collected during the meeting at Tioxide (M) Sdn Bhd. The data collection was grouped into 6 months period.

3.4 DATA EVALUATION

The analysis is done based on the capability analysis study by statistical process control. The data firstly analyze by using control chart. X - Bar chart and R-Bar chart has chosen to see the spread of the data collection whether in control or out of control. The capability analysis will predict the process in capable or incapable. The evaluation is measured based on the specification and target from titanium tioxide's manufacturer. From the data evaluation, a further discussion based on the control chart and capability analysis has been done come out with that give information for the process itself. The opportunity to improve the process based on the benchmark of Cp and Cpk value has been detected.

3.5 STATISTICAL PROCESS CONTROL

Statistical process control (SPC) involves using statistical techniques to measure and analyze the variation in processes. Most often used for manufacturing processes, the intent of SPC is to monitor product quality and maintain processes to fixed targets. Statistical quality control refers to using statistical techniques for measuring and improving the quality of processes and includes SPC in addition to other techniques, such as sampling plans, experimental design, variation reduction, process capability analysis, and process improvement plans.

SPC is used to monitor the consistency of processes used to manufacture a product as designed. It aims to get and keep processes under control. No matter how good or bad the design, SPC can ensure that the product is being manufactured as designed and intended. Thus, SPC will not improve a poorly designed product's reliability, but can be used to maintain the consistency of how the product is made and, therefore, of the manufactured product itself and its as-designed reliability.

A primary tool used for SPC is the control chart, a graphical representation of certain descriptive statistics for specific quantitative measurements of the manufacturing process. These descriptive statistics are displayed in the control chart in comparison to their "in-control" sampling distributions. The comparison detects any unusual variation in the manufacturing process, which could indicate a problem with the process. Several different descriptive statistics can be used in control charts and there are several different types of control charts that can test for different causes, such as how quickly major vs. minor shifts in process means are detected. Control charts are also used with product measurements to analyze process capability and for continuous process improvement efforts.

3.5.1 The idea of statistical process control

The idea of statistical process control comes with a goal that is to make a process stable over time and then keep it stable unless planned changes are made. All process has variation and statistical stability means the pattern of variation remains stable, not there is no variation in the variable measured. A common cause of variation is the inherent variability of the system due to many small causes that are always present. When the normal functioning of the process is disturbed by some unpredictable event, special cause variation is added to the common cause variation. The cause of this type of variation has to eliminate to restore stability to the process.

3.5.2 Benefits of Statistical Process Control

Statistical process control provides surveillance and feedback for keeping processes in control. It gives signals when a problem with the process has occurred and detects assignable causes of variation. Beside that, statistical process control accomplishes process characterization and reduces need for inspection.

Statistical process control also a tool to monitors process quality and provides mechanism to make process changes and track effects of those changes.

Once a process is stable (assignable causes of variation have been eliminated), provides process capability analysis with comparison to the product tolerance

3.5.3 Process Control Chart

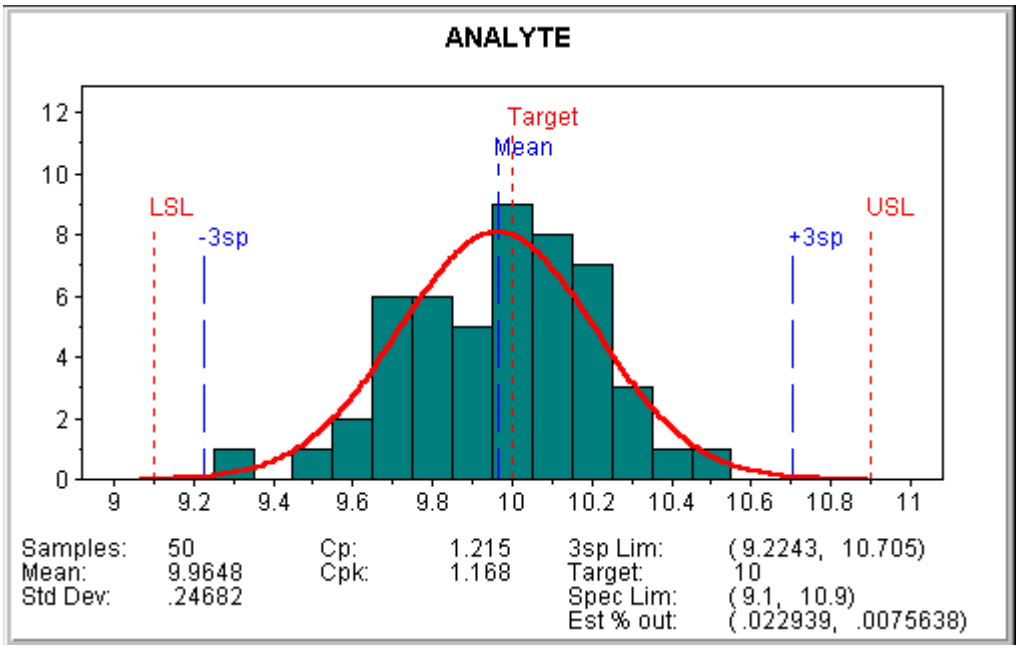


Figure 3.0 Example of process control chart

This analysis as figure 3.0 above provides a great deal of information on analytical performance. When Cpk is greater than 1.0, the delivered analysis is within acceptable limits more than 99.7 percent of the time. Note that Cpk is lower than Cp, reflecting the fact that our analysis exhibits a small negative bias.

Process control charts are fairly simple-looking connected-point charts. The points are plotted on an x/y axis with the x-axis usually representing time. The plotted points are usually averages of subgroups or ranges of variation between subgroups, and they can also be individual measurements. Some additional horizontal lines representing the average measurement and control limits are drawn across the chart. Notes about the data points and any limit violations can also be displayed on the chart.

Statistical Process Control (SPC) provides a way to monitor chemical and other processes. This thesis focuses on continuous chemical processes and how the process and quality control utilize SPC.

In a continuous chemical process, two types of charts are commonly used: individual value or X-bar charts and moving range (MR) or R-bar charts. X-bar charts are used on a regular basis to monitor the process during a time of change. For example, an R-bar chart would be appropriate if you were changing the feeds to the process. The R-bar chart weights more recent data more heavily than historical data.

The chemical industry typically uses one of two types of process control. 3-sigma control specifies quality limits nearly equal to process limits. 6-sigma control specifies quality limits that are twice as large as control limits.

The process limits are those which define boundaries of operation for the process or an acceptable operating value. The quality control limits are those used to "grade" material. The term "quality limits" will refer to the grade or top grade material limits. The limits of these other grades vary accordingly. Essentially, the farther away from specifications a product is, the lower the grade, and its value decreases sharply.

3.5.3 Control Chart

Control charts are statistical tools that monitor a process and alert us when the process has been disturbed so that it is now out of control. This is a signal to find and correct the cause of the disturbance. The example of control chart is shown below:

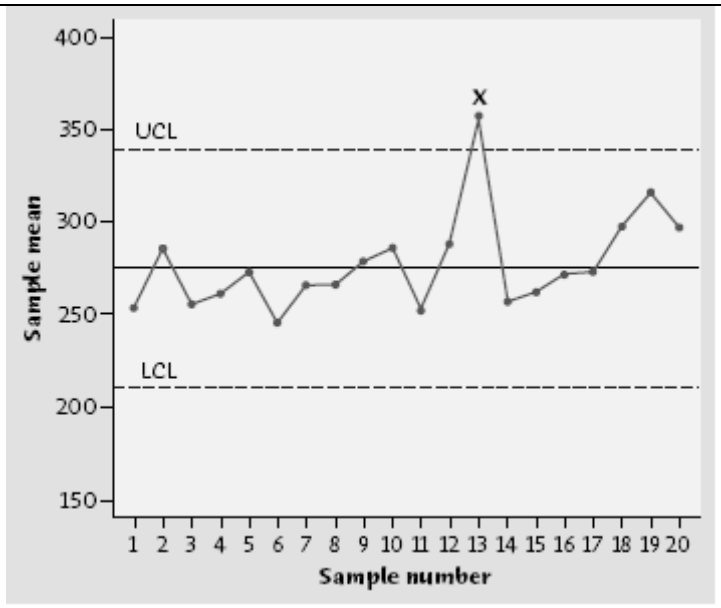


Fig 3.1 Example of X bar chart in Control Chart

*The point X indicates a data point for sample number 13 that is "out of control."

3.5.5 SPC- X Bar Charts

Start by calculating the average for the data points:

$$\overline{X} = \frac{\sum_{i=1}^{n} X_i}{n} \tag{3.1}$$

Now,

$$\text{UCL (calculated)} = \overline{X} + Z\sigma_x \tag{3.2}$$
$$\text{LCL (calculated)} = \overline{X} - Z\sigma_x$$

$$\sigma_x = \frac{\sigma}{\sqrt{n}} \tag{3.3}$$

$$\sigma = \text{standard deviation} = \left[\frac{\sum (X_i - \overline{X})^2}{n-1}\right]^{\frac{1}{2}} \tag{3.4}$$

3.5.6 Procedure for Applying Control Chart to A Process

3.5.6.1 Chart Set Up Stage

There are a few step that need to follow to perform the chart set up stage. The step is shown below.

a) Collect data from the process.
b) Establish control by uncovering and removing special causes.
c) Set up control charts to maintain control.

3.5.6.2 Process Monitoring

Process monitoring in analyzing the data is really important. It can tell the condition of data collection whether in a good condition or bad condition. The objective is to observe those process variables which have proven to be the best indicators of the quality of the manufacturing operation.Below is the steps to perform the process monitoring.

a) Observe the process operating in control for some time.
b) Understand usual process behavior.
c) Have a long run of data from the process.
d) Keep control charts to monitor the process because a special cause could erupt at any time.

Process monitoring condition is a process to measure a quantitative variable (data) that has a normal distribution**.** The process has been operating in control for a long period, so that consider the distribution of data as the process remains in control.

3.5.7 General Procedure for a Control Charts

1. Take samples of size *n* from process at regular intervals. Plot the means *x* of these samples against the order in which the samples were taken.
2. The sampling distribution of *x* under the process monitoring conditions is Normal with a mean and standard deviation.
3. The 99.7 part of the 68-95-99.7 rule for Normal distributions says that as long as the process remains in control, 99.7% of the values of *x* will fall within three standard deviations of the mean. Draw dashed control limits on the chart at these heights. The control limits mark off the range of variation in sample means that is expected when the process remains in control.
4. The chart produces an out-of-control signal when a plotted point lies outside the control limits.

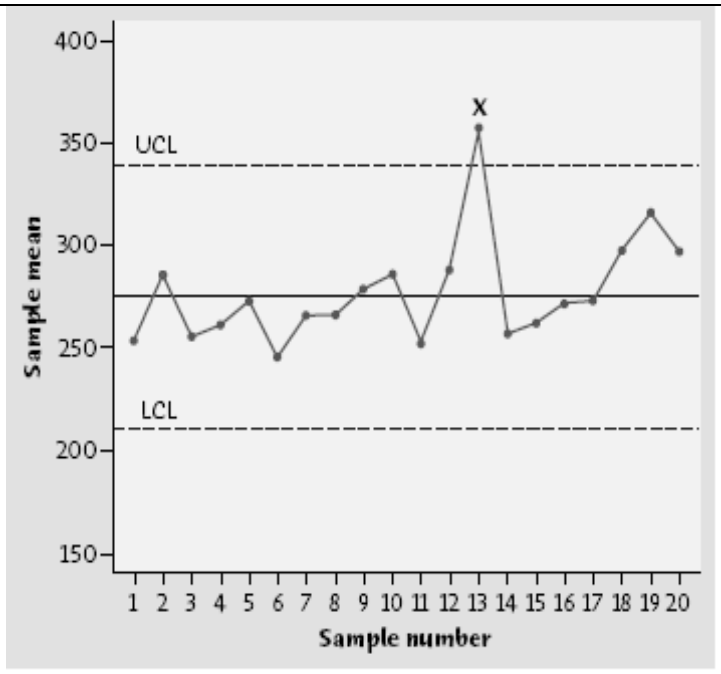


Figure 3.2 Example of X charts for process monitoring

3.5.8 SPC – R Bar Charts

R-bar charts utilize chart factors that are typically found in statistical references. The UCL (calculated) and LCL (calculated) are defined by:

$$\mathrm{UCL\,(calculated)} = D_4\,(\overline{R}) \tag{3.6}$$

$$\mathrm{LCL\,(calculated)} = D_3\,(\overline{R}) \tag{3.7}$$

$$\overline{R} = \frac{\sum_{i=2}^{n} MR_i}{n-1} \tag{3.8}$$

where MR (moving range) is the absolute value of the difference between the current data point and the preceding data point. The number of sub-groups is an area that most people do not agree upon.

3.5.9 Uses oF R Bar Charts.

The R bar chart is used to Keep a record of when process changes or feed changes occurred. It also Record of how long the process took to stabilize and Show long history of a process or piece of equipment. The R-bar charts did not tell about the actual value of the results, only deviations from one result to the next.

3.5.10 The Purpose Of Control Charts

Control charts are an essential tool of continuous quality control. Control charts monitor processes to show how the process is performing and how the process and capabilities are affected by changes to the process. This information is then used to make quality improvements. Control charts are also used to determine the capability of the process. They can help identify special or assignable causes for factors that impede peak performance.

3.5 11 Uses of Control Charts

It is important to emphasize that control charts have several important, somewhat sequential, roles in quality improvement work. The control charts is used to understand the current and past process performance and its degree of consistency and predictability. It is also establishing a "state of statistical control" by identifying and removing causes of unnatural (or "special cause") variation so as to achieve a consistent and predictable level of process quality over time.

Besides that, control charts is the way to improve a process by identifying and removing causes of natural (or “common cause") variation and by testing whether interventions result in an improvement. It also monitoring for process deterioration and "holding the gains" by identifying special causes of unnatural variation when they arise in the future

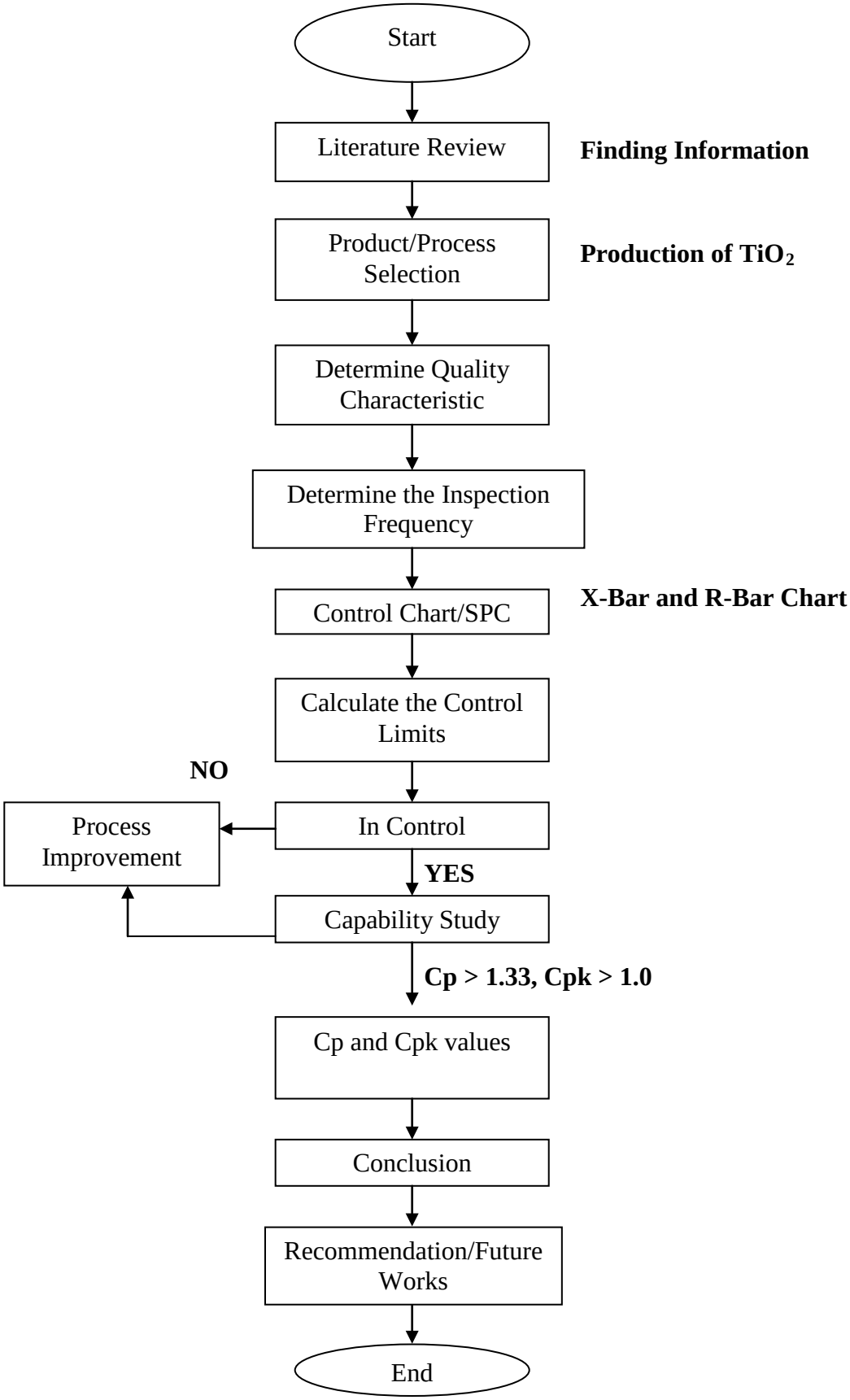
3.6 MINITAB SOFTWARE

Minitab is a general purpose statistical system. It is a flexible and powerful tool especially for those who have no previous experience with computers. The commands used in Minitab tend to be simpler and more conversational than commands found in other software packages.

Additionally, the commands generally correspond to the major steps taken to solve a statistical problem by hand. While Minitab was originally designed for students in introductory statistics courses, its use has expanded to a wide variety of research areas. Minitab now incorporates procedures for regression, multivariate analysis, nonparametric, and time series analysis.

In this thesis, the Minitab software had been chosen as a software to analyze all the data collection. It was chosen due to the flexibility usage and one of the powerful tool to perform the process capability analysis.

3.7 FLOW CHART



CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

This chapter will describe the result and discussion from the analyzing process. This chapter is the sequences from the previous chapter. It displays the whole result involving all the control parameters gather from the data collection and data evaluation.

Minitab 13 was chosen as software to perform the process capability analysis in this thesis. The target and specification needed in every process was key in through this software in order to get the value of Cp and Cpk.

From this chapter, it shows how important process capability analysis in industry and benefit of implementation of this analysis. This method inspects the capability of the process to demand the specification from the market that always expecting the higher quality from the manufacturer.

4.2 ANALYSIS OF DATA

Regarding to parameters controlled, those are Grey Stage Time (GST) that was divided in to GST 1, GST 2, GST 3, GST 4, Precipitation Recovery, Crystal Size & Crystal Size Distribution and Particle Size & Particle Size Distribution, they showed that most of the Cp and Cpk value were in the capable state. The further result was displayed below.

4.3 GREY STAGE TIME (GST)

The Grey Stage Time was divided into four. Those are Grey Stage Time 1 (GST 1), Grey Stage 2 (GST 2), Grey Stage 3 (GST3) and Grey Stage 4(GST4). It all happened in precipitation tank.

Grey stage time happen when a suspension is in transmission from black to white. The grey stage time corresponds to the point when the rate of change of reflectance with time reaches a maximum.500 samples was taken during 6 months of period.

4.3.1 Grey Stage Time 1

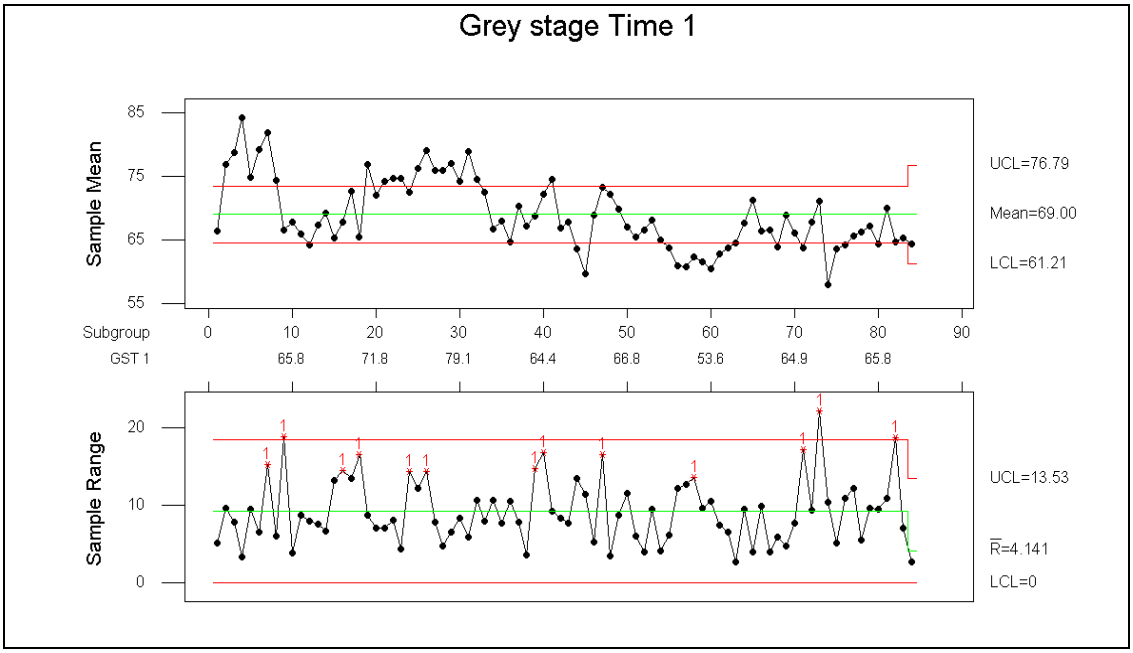


Figure 4.0 , X bar-R chart for (GST 1)

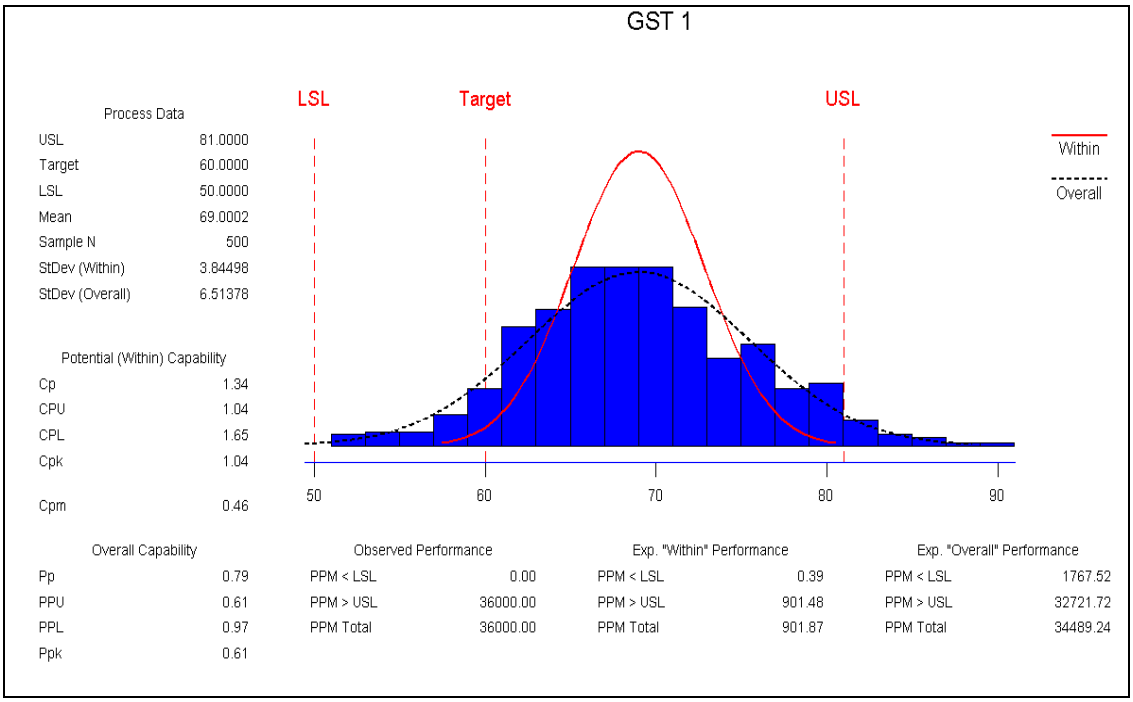


Figure 4.1 Process capability for (GST 1)

The graph above displayed the result of grey stage time 1 (GST). The figure 4.0 represented the X bar-R chart. The R bar chart (second lower) shows 13 point fall outside the control limits (representing by red asterisk). It can be consider as in control state because the point is 13 points out of 500 samples but an inspection need to be done to reduce the out of control point. The X bar chart shows the normal distribution of the process which the mean, X equal to 69.002. The next is step to calculate the Cp and Cpk.

The Figure 4.1 represents the Cp and the Cpk value. The upper control limit is 81 min and lower control limit is 50 min .The target is 60 min, while the standard deviation is 3.84438. From the figure, the value for Cp is 1.34 and Cpk is 1.04. Both of these values are in capable state. And it is optional for the company to do improvement at this stage of process.

Checking by Manual calculation by using mathematical formulation:

$$Cp = (USL - LSL) / 6\sigma$$

$$Cp = (81 - 50.002)/6(3.84438)$$
$$= 1.34$$

$$Cpk = (USL - X)/ 3 \text{ Sigma} \quad OR \quad (X - LSL)/ 3\sigma$$
$$Cpk = (81-69.00)/ 3(3.84438)$$
$$= 1.04$$

Both of these values are in capable state.

4.3.2 Grey Stage Time 2 (GST2)

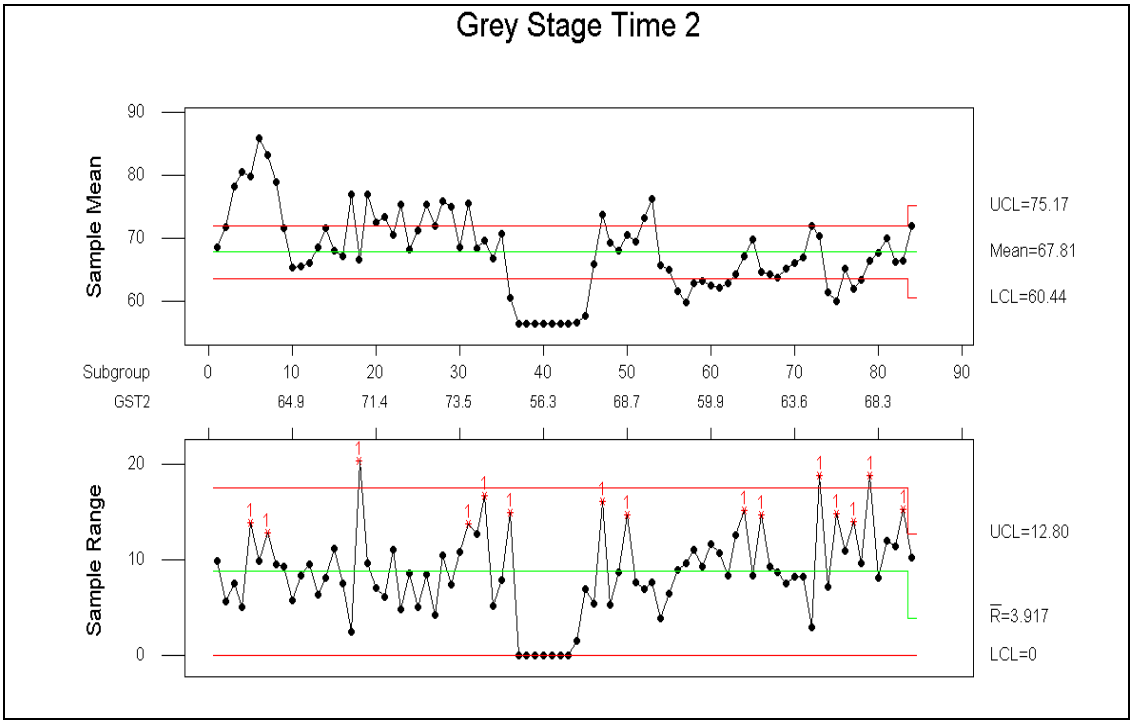


Figure 4.2 X bar R chart for GST 2

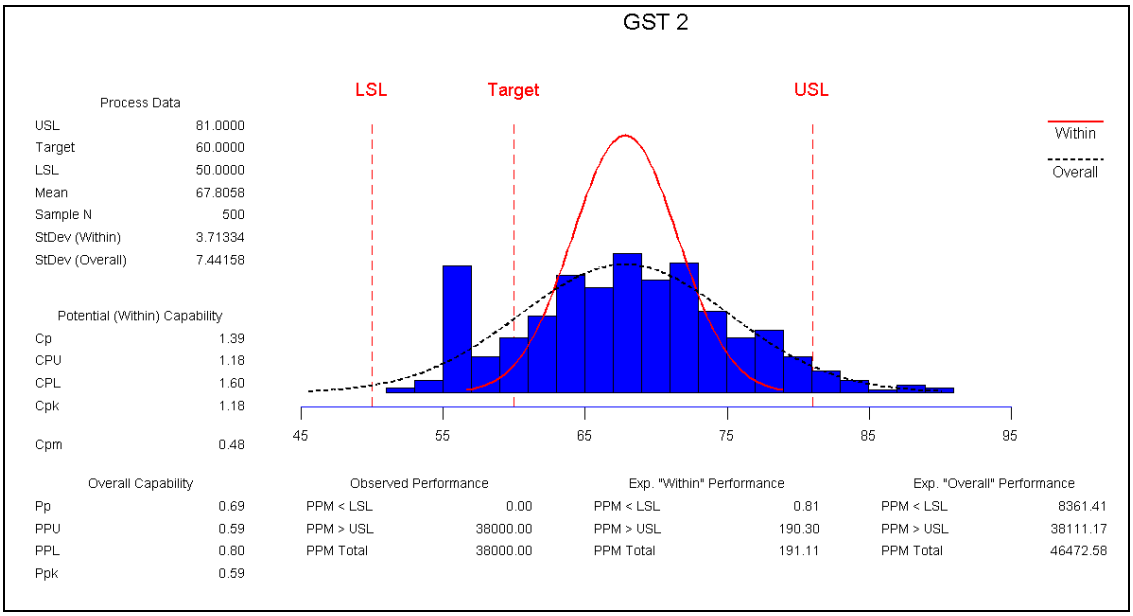


Figure 4.3 Process capability for GST 2

The figure 4.2 represented the X bar-R chart of Grey Stage Time 2 (GST 2). The R bar chart (second lower) shows 15 point fall outside the control limits (representing by red asterisk). It can be consider as in control state because the point is 15 points out of 500 samples, but an inspection need to be done to reduce the out of control point. The X bar chart shows the normal distribution of the process which the mean, X equal to 67.81. So, the next step to calculate the Cp and Cpk value may be proceed.

The Figure 4.3 represents the Cp and the Cpk value. The upper control limit is 81 min and lower control limit is 50 min. The target is 60 min, while the standard deviation is 3.71334. From the figure, the value for Cp is 1.39 and Cpk is 1.18. Both of these values are in capable state. And it is optional for the company to do improvement at this stage of process.

Checking by Manual calculation by using mathematical formulation:

$$Cp = (USL - LSL) / 6\sigma$$

$$Cp = (81\text{-}50)/6(3.71334)$$

=1.39

Cpk = (USL – X)/ 3σ OR (X – LSL)/ 3σ

Cpk = (81-67.81) / 3(3.71334)

= 1.18

Both of these values are in capable state.

4.3.3 Grey Stage Time 3 (GST 3)

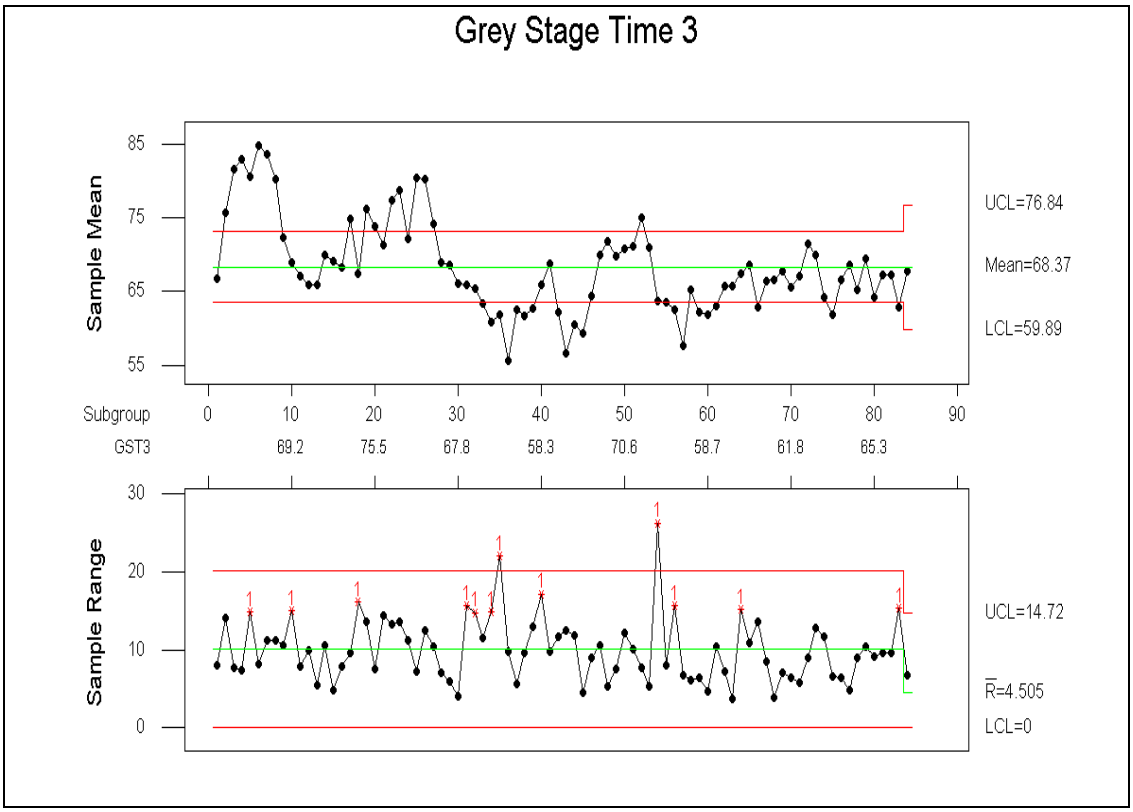


Figure 4.4 X bar R chart for GST 3

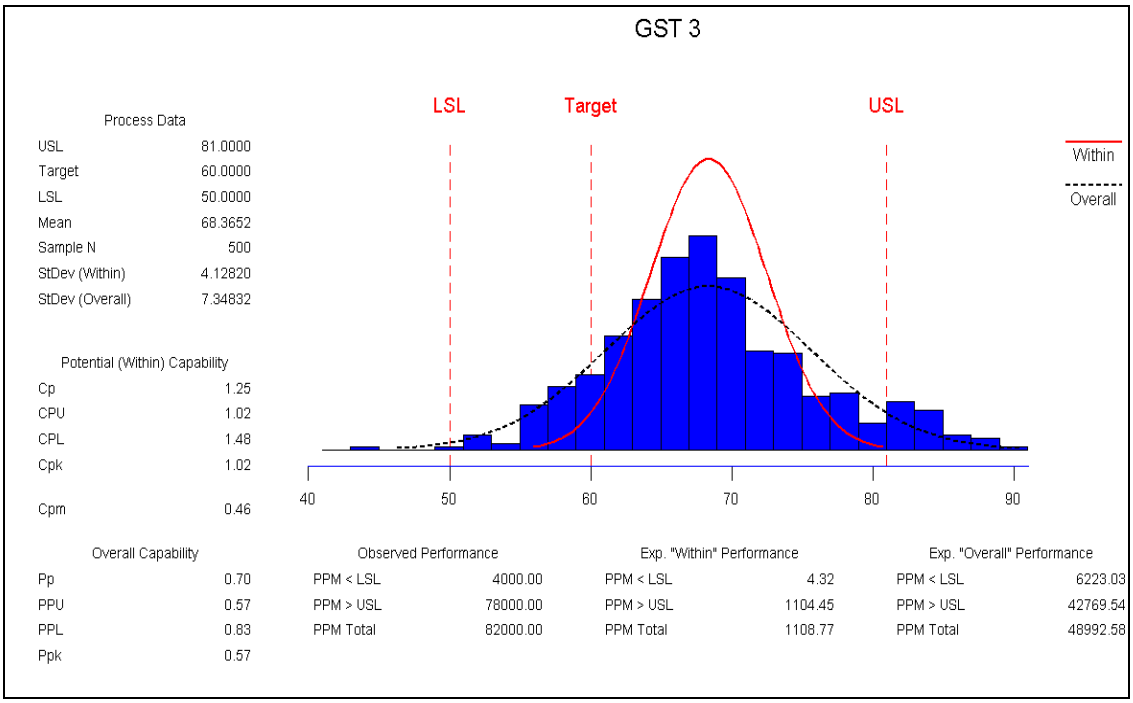


Figure 4.5 Process capability for GST 3

Graph above displayed the result of grey stage time 3 (GST 3). The figure 4.4 represented the X bar-R chart. The R bar chart (second lower) shows 12 point fall outside the control limits (representing by red asterisk).It can be consider as in control state because the point is 12 points out of 500 samples, but an inspection need to be done to reduce the out of control point. The X bar chart shows the normal distribution of the process which the mean, X equal to 68.37. The next is step to calculate the Cp and Cpk .

The Figure 4.5 represents the Cp and the Cpk value. The upper control limit is 81 min and lower control limit is 50 min. The target is 60 min, while the standard deviation is 4.12820. From the figure, the values for Cp are 1.25 and Cpk is 1.02. The Cp value is not capable due to the small value when tolerance width divided by the process width. So, the tolerance width should be increase to get the better value of Cp. The Cpk is in capable state. An improvement need to be done to make the process in capable.

Checking by manual calculation by using mathematical formulation

$$Cp = (USL - LSL) / 6\sigma$$

$$Cp = (81-50)/6(4.12820)$$

$$= 1.25$$

$$Cpk = (USL - X)/ 3\sigma \quad OR \quad (X - LSL)/ 3\sigma$$

$$Cpk = (81-68.3652) / 3(4.12820)$$

$$= 1.02$$

The Cp value is incapable while the Cpk value is capable.

4.3.4 Grey Stage Time 4 (GST 4)

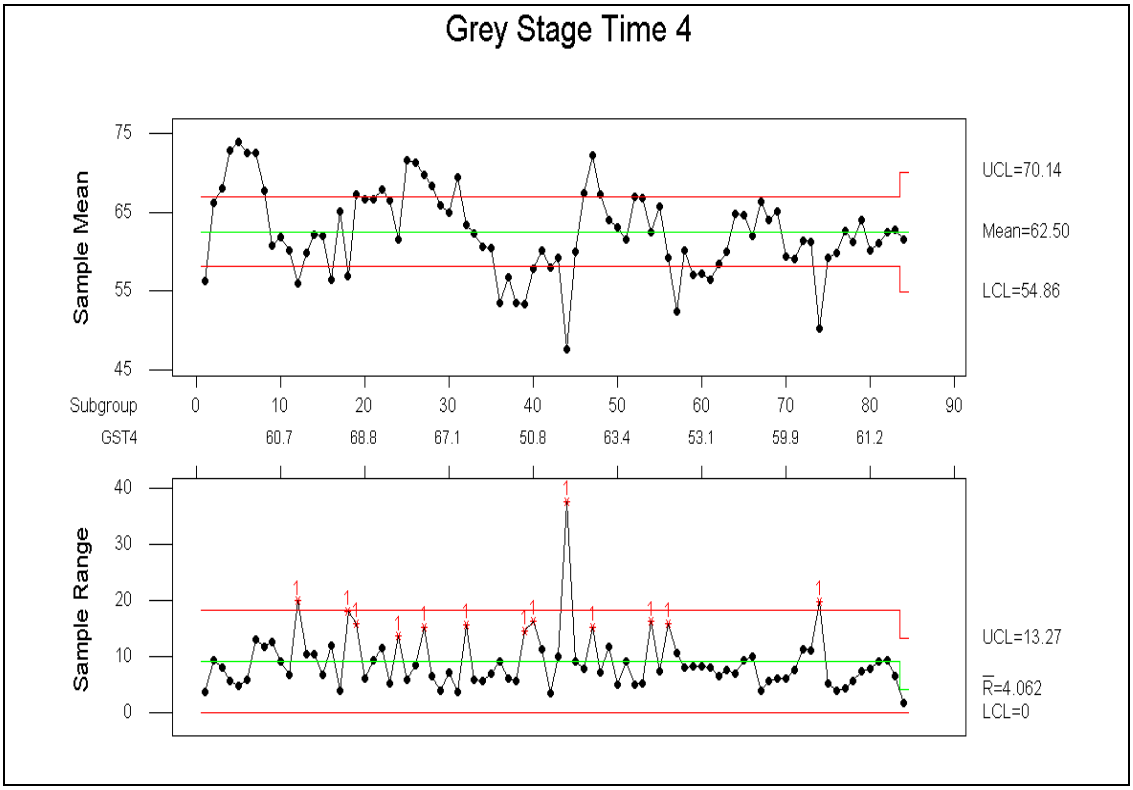


Figure 4.6 X bar R chart for GST 4

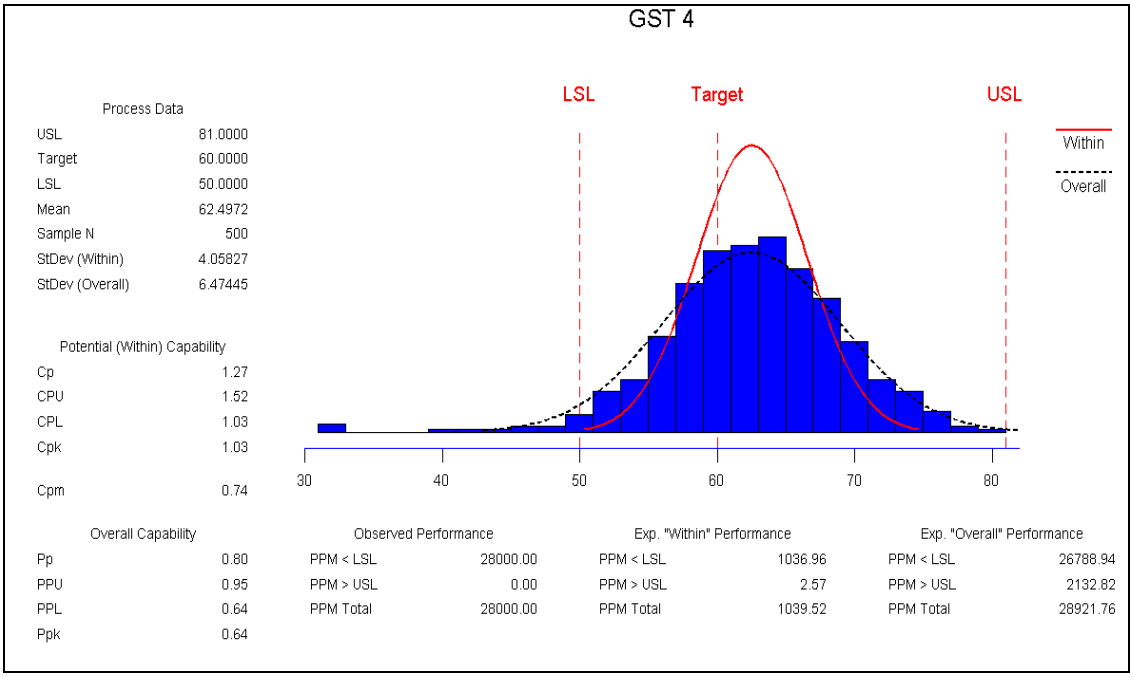


Figure 4.7 Process capability for GST 4

The figure 4.6 represented the X bar-R chart of Grey Stage Time 4 (GST 4). The R bar chart (second lower) shows 13 point fall outside the control limits (representing by red asterisk).It can be consider as in control state because the point is 13 points out of 500 samples, but an inspection need to be done to reduce the out control of point. The X bar chart shows the normal distribution of the process which the mean, X equal to 62.4972. The next is step to calculate the Cp and Cpk value.

The figure 4.7 represents the Cp and the Cpk value. The upper control limit is 81 min and lower control limit is 50 min. The target is 60 min, while the standard deviation is 4.05827.From the figure, the values for Cp are 1.27 and Cpk is 1.03. The Cp value is not capable due to the small value when tolerance width divided by the process width. So, the tolerance width should be increase to get the better value of Cp. The Cpk is in capable state. An improvement need to be done to make the process in capable.

Checking by manual calculation by using mathematical formulation

$$Cp = (USL - LSL) / 6\sigma$$
$$Cp = (81-50)/6(4.05827)$$
$$= 1.27$$

$$Cpk = (USL - X)/ 3\sigma \quad OR \quad (X - LSL)/ 3\sigma$$
$$Cpk = (62.4972-50) / 3(4.05827)$$
$$= 1.03$$

The Cp value is incapable while the Cpk value is capable. Below is the table of Cp and Cpk value in Grey Stage Time (GST) process.

Table 4.0 Cp and Cpk value based on Grey Stage Time

Grey Stage Time	Cp	Cpk
GST 1	1.34	1.04
GST 2	1.39	1.18
GST 3	*1.25	1.02
GST 4	*1.27	1.03

* Indicates process incapable and need improvement

The * (star) sign above indicate the two process that was classified as incapable process which are need some improvement. The main cause of state is when then value of process width is smaller than the process width. An improvement need to be done in order to improve the state of the process. The value of Cp will affect the productivity of the product that will contribute to the customers satisfaction.

4.4 Precipitation Recovery

Precipitation recovery happens in precipitation tank. It is measure in percentage. The recovery affected the whiteness of pigment. The higher the recovery, the greater of whiteness of pigment will produce. It is due to reduction of Fe^{3+} to Fe^{2+} .

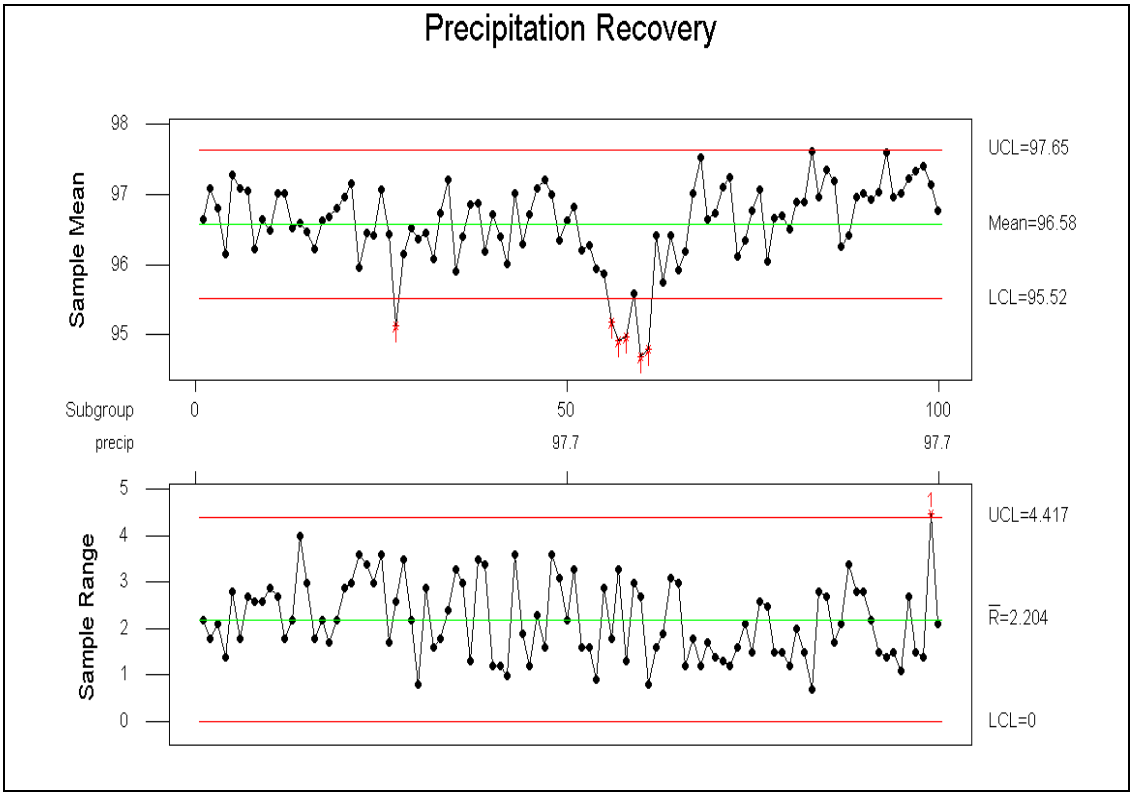


Figure 4.8 X bar R chart for Precipitation Recovery

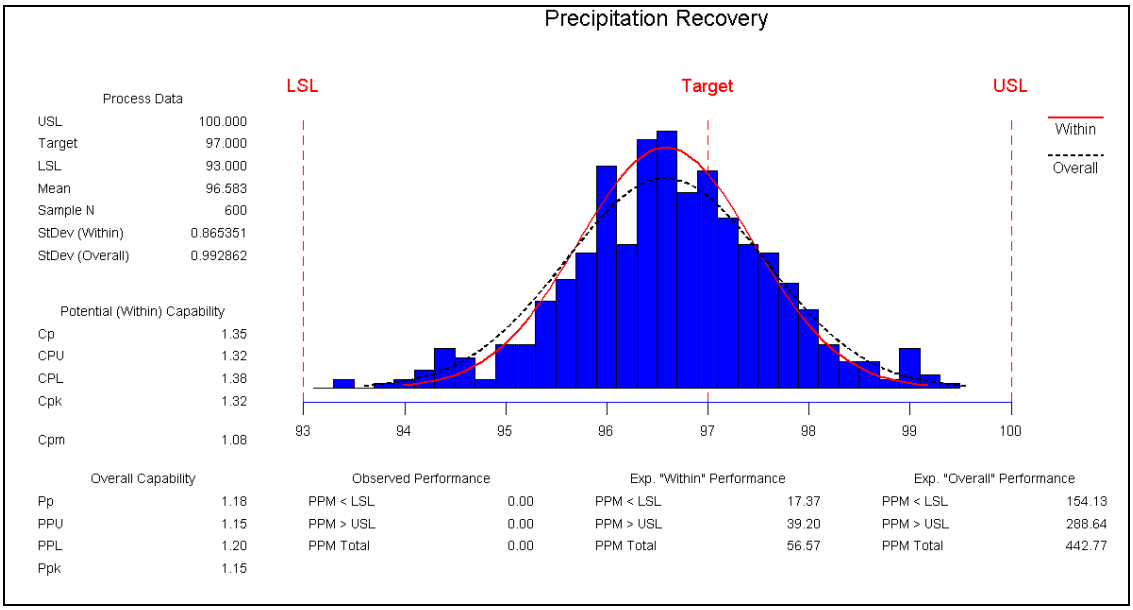


Figure 4.9 Process capability for Precipitation Recovery

From the graph above, it displayed the result of precipitation recovery. The figure 4.8 represented the X bar-R chart. The R bar chart (second lower) shows 6 point fall outside the control limits (representing by red asterisk). It can be consider as in control state because the point is 6 points out of 600 samples, but an inspection need to be done to reduce the out of control point . The X bar chart shows the normal distribution of the process which the mean, X equal to 96.58 %. The next step is to calculate the Cp and Cpk value.

The figure 4.9 represents the Cp and the Cpk value. The upper control limit is 100 % and the lower control limit is 93 %. The target is 97 %, while the standard deviation is 0.865351.From the figure, the values for Cp are 1.35 and Cpk is 1.03. The Cp value is not capable but the Cpk is in capable state. It is optional for the company to do improvement at this stage of process.

Checking by manual calculation by using mathematical formulation

$$Cp = (USL - LSL) / 6\sigma$$

$$Cp = (100-93)/6(0.865351)$$

=1.35

Cpk = (USL – X)/ 3σ OR (X – LSL)/ 3σ

Cpk = (100-96.58) / 3(0.865351)

= 1.32

The Cp value is incapable while the Cpk value is capable.

4.5 Crystal Size

Crystal size is referring to the equivalent diameter of the smallest pigment unit. It usually measured in micron. Crystal size happens in calciner, where the formation of TiO_2 crystal started.

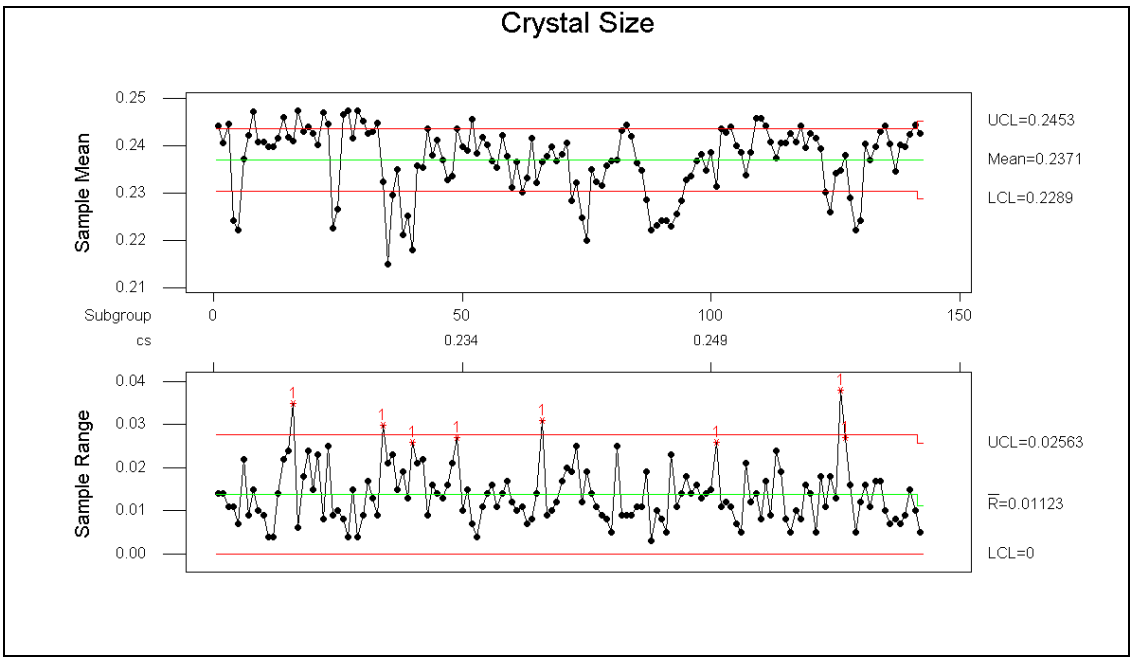


Figure 4.10 X bar R chart for Crystal Size

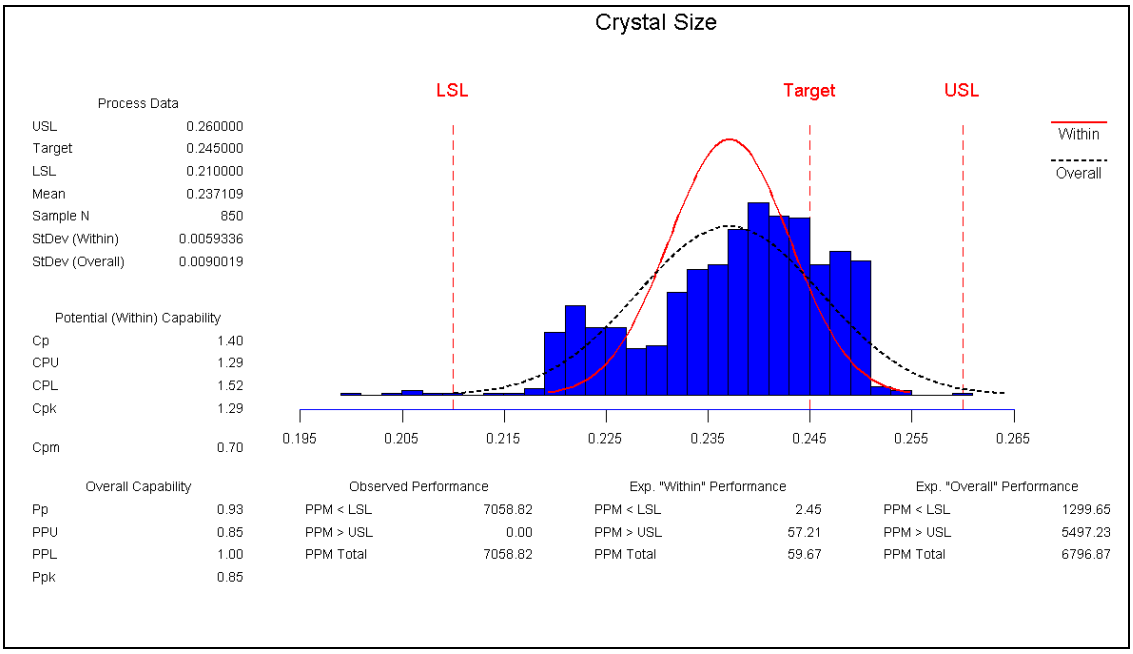


Figure 4.11 Process capability for Crystal Size

. The figure 4.10 represented the X bar-R (second lower) chart of crystal size. The R bar chart (second lower) shows 12 points fall outside the control limits (representing by red asterisk). It can be consider as in control state because the point is12 points out of 850 samples ,but an inspection need to be done to reduce the out of control point. The X bar chart shows the normal distribution of the process which the mean, X equal to 0.329 micron. The next step is to calculate the Cp and Cpk value.

The figure 4.11 represents the Cp and the Cpk value. The upper control limit is 0.26 micron and the lower control limit is 0.21 micron, while the standard deviation is 0.0059336. From the figure, the values for Cp are 1.40 and Cpk is 1.29. The Cp value is not capable but the Cpk is in capable state. It is optional for the company to do improvement at this stage of process.

Checking by manual calculation by using mathematical formulation

$$Cp = (USL - LSL) / 6\sigma$$

$$Cp = (0.26-0.21)/ 6(0.0059336)$$

=1.40

Cpk = (USL – X)/ 3σ OR (X – LSL)/ 3σ

Cpk = (0.26-0.237109)/ 3(0.0059336)

= 1.29

Both of Cp and Cpk values are in capable state.

4.5.1 Crystal Size Distribution

In manufacture TiO_2, not all crystals which exit the calciner are of the same size, some will have growth more than others. The crystals size distribution refers to the spread of sizes crystals growth and shape are controlled by the calciner addition mode, the temperature profile in the calciner and nuclei mode

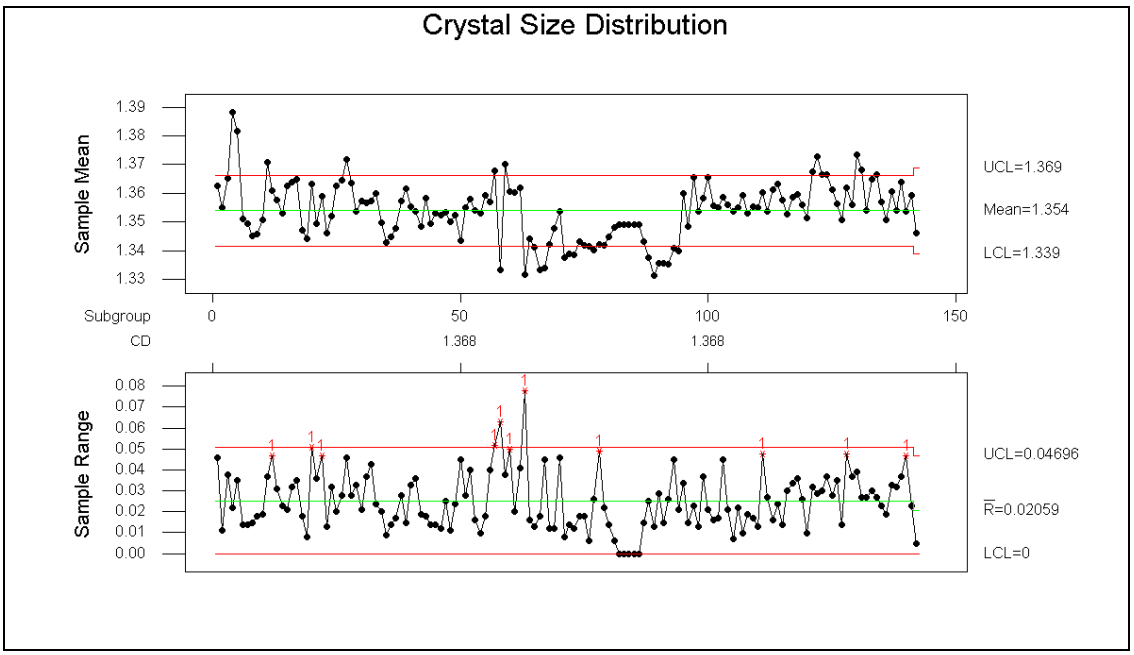


Figure 4.12 X bar R chart for Crystal Size Distribution

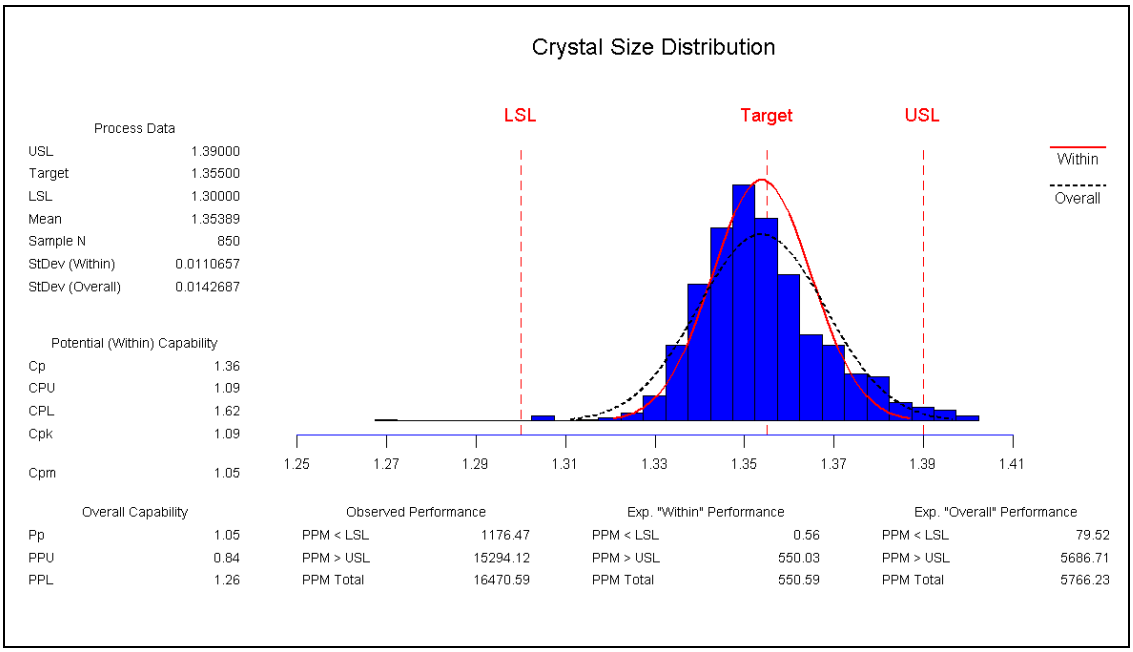


Figure 4.13 Process capability for Crystal Size Distribution

From the graph above, it displayed the result of crystal size distribution. The figure 4.12 represented the X bar-R chart. The R bar chart (second lower) shows 11points fall outside the control limits (representing by red asterisk). It can be consider as in control state because the point is12 points out of 850 samples but an inspection need to be done to reduce the out of control point. The X bar chart shows the normal distribution of the process which the mean, X equal to1.35399. The next step is to calculate the Cp and Cpk value.

The Figure 4.13 represents the Cp and the Cpk value. The upper control limit is 1.39 and the lower control limits is1.30, while the standard deviation is 0.0110657. From the figure, the values for Cp are 1.36 and Cpk is1.09. The Cp value is not capable but the Cpk is in capable state. It is optional for the company to do improvement at this stage of process.

Checking by manual calculation by using mathematical formulation

$$Cp = (USL - LSL) / 6\sigma$$

$$Cp = (1.39\text{-}1.30)/\ 6(0.0110657)$$
$$= 1.36$$

$$Cpk = (USL - X)/\ 3\sigma \quad OR \quad (X - LSL)/\ 3\sigma$$
$$Cpk = (1.39\text{-}1.35399)/\ 3(0.0110657)$$
$$= 1.09$$

Both of Cp and Cpk values are in capable state.

4.6 Particle Size

In the TiO_2 sense, a particle may be single crystal or strongly bound agglomerate of general crystals. Particle size is the average of all the TiO_2 particles in the milled slurry after calcination.

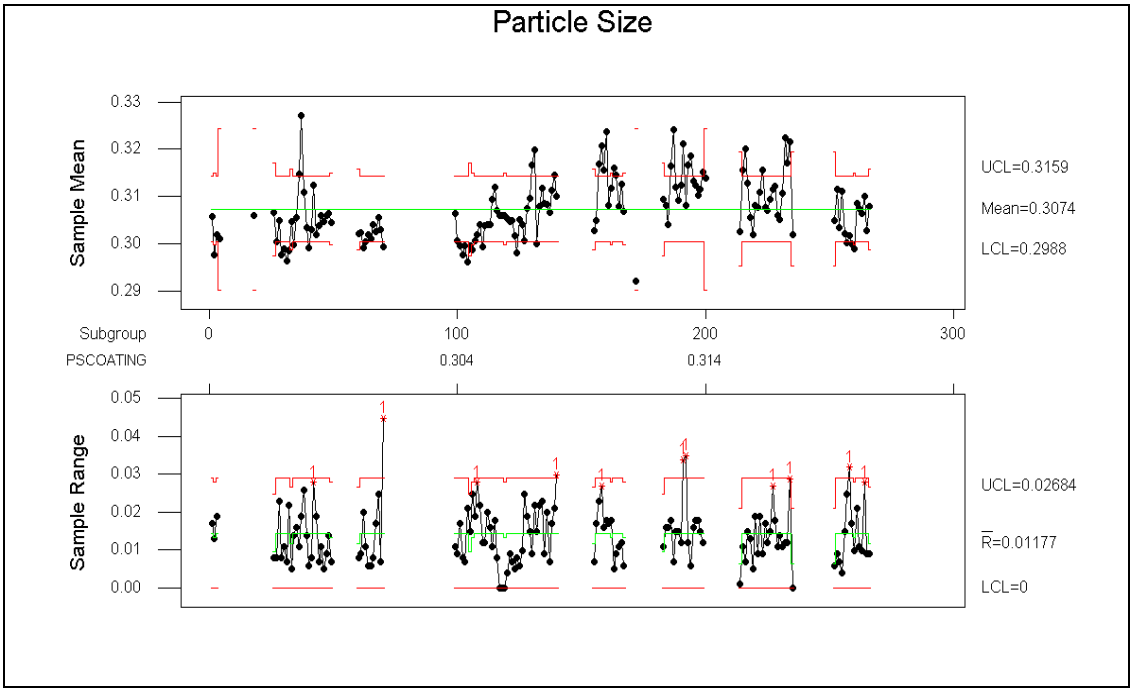


Figure 4.14 X bar R chart for Particle Size

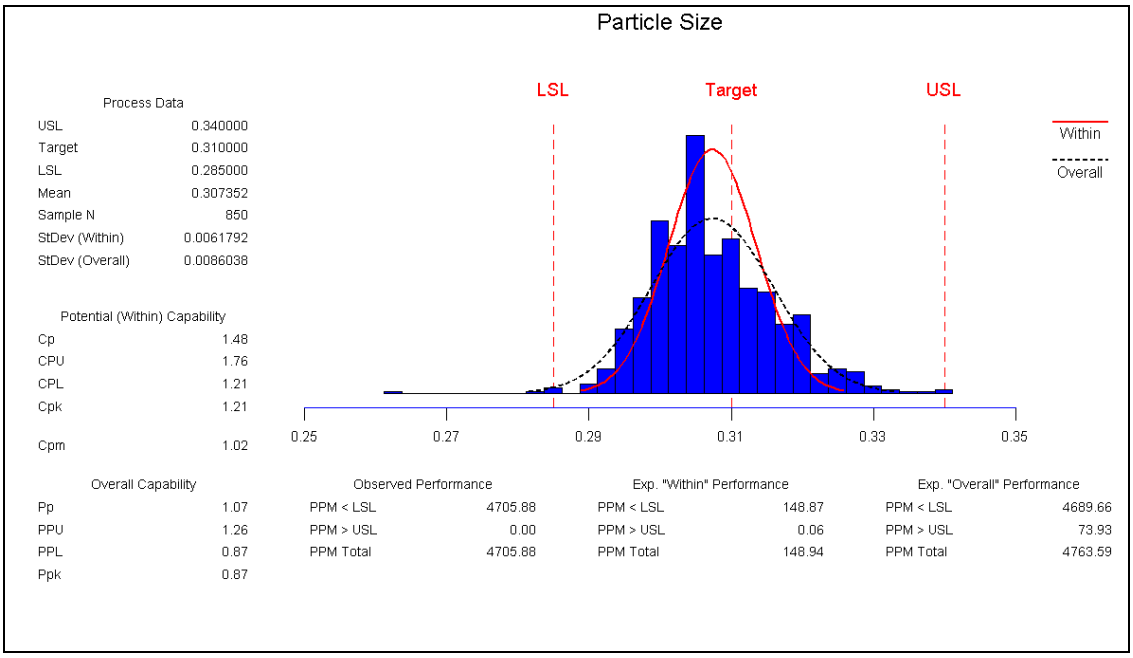


Figure 4.15 Process capability for Particle Size

From the graph above, it displayed the result of particle size. The figure 4.14 represented the X bar-R chart. The R bar chart (second lower) shows 10 points fall outside the control limits (representing by red asterisk). But it can be consider as in control state because the point is10 points out of 850 samples. The X bar chart shows the normal distribution of the process which the mean, X equal to 0.307352 micron. The shape of this graph quite different compare to the other graph because of there are data which overlapping with others. But, the data is still in the normal distribution. The next step is to calculate the Cp and Cpk value.

The Figure 4.15 represents the Cp and the Cpk value. The upper control limit is 0.34 micron and the lower control limit is 0.285 micron, while the standard deviation is 0.0061792. From the figure, the values for Cp are 1.48 and Cpk is 1.21. The Cp value is not capable but the Cpk is in capable state. It is optional for the company to do improvement at this stage of process.

Checking by manual calculation by using mathematical formulation

$$Cp = (USL - LSL) / 6\sigma$$

$$Cp = (0.34-0.285)/\ 6(0.0061792)$$
$$=1.48$$

$$Cpk = (USL - X)/\ 3\sigma \ \ OR \ \ (X - LSL)/\ 3\sigma$$
$$Cpk = (0.307352- 0.285)/\ 3(0.0061792)$$
$$= 1.21$$

Both of Cp and Cpk values are in capable state.

4.6.1 Particle Size Distribution.

Particle size distribution refers to a range of agglomerate sizes. It also refers to the spread of the distribution.

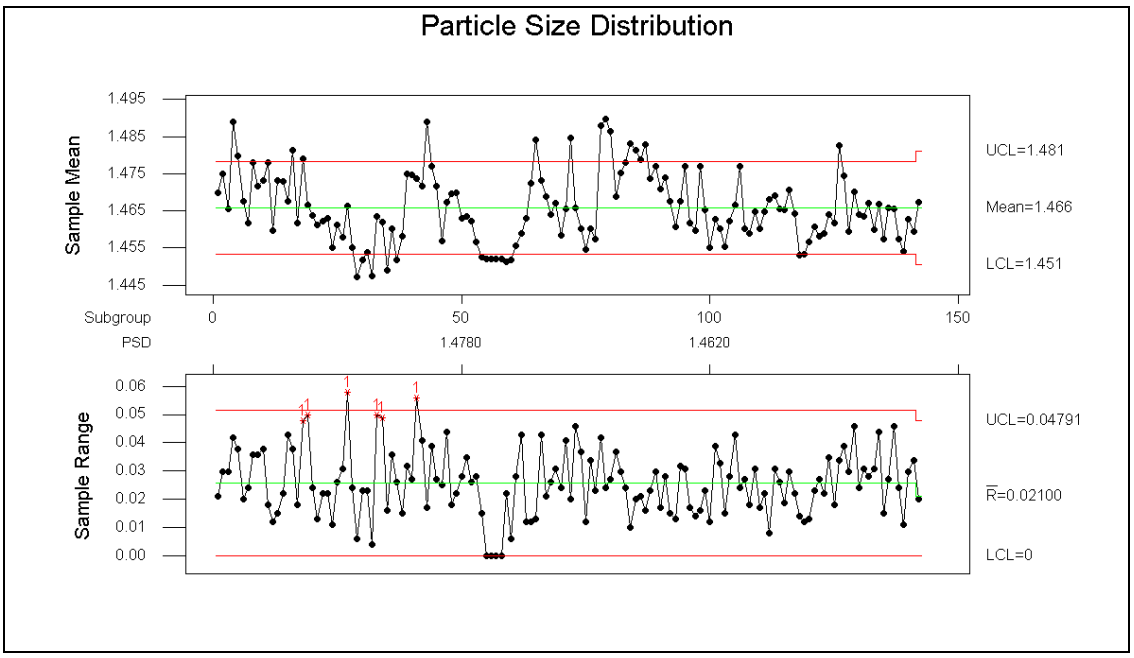


Figure 4.16 X bar R chart for Particle Size Distribution

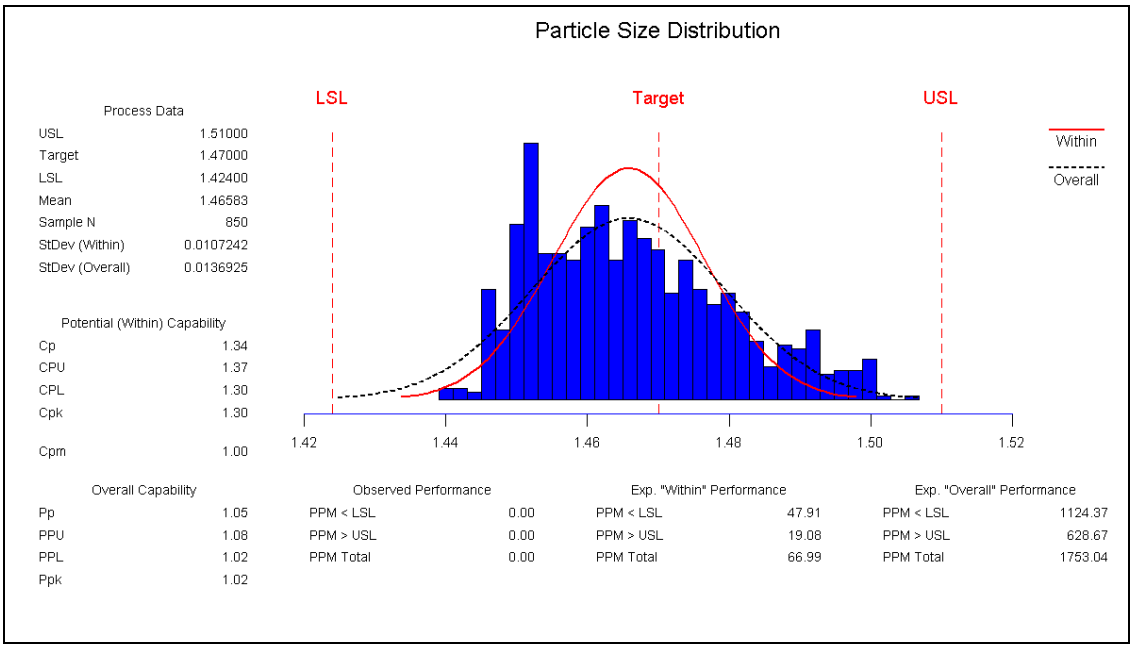


Figure 4.17 Process Capability for Particle Size Distribution

From the graph above, it displayed the result of particle size distribution. The figure 4.16 represented the X bar-R chart. The R bar chart shows 6 points fall outside the control limits (representing by red asterisk).It can be consider as in control state because the point is 6 points out of 850 samples, but an inspection need to be done to reduce the out of control point. The X bar chart shows the normal distribution of the process which the mean, X equal to1.46583. The next step is to calculate the Cp and Cpk value.

The Figure 4.17 represents the Cp and the Cpk value. The upper control limit is 1.510 and the lower control limit is 1.424, while the standard deviation is 0.0107242. From the figure, the values for Cp are 1.34 and Cpk is 1.30 The Cp value is not capable but the Cpk is in capable state. It is optional for the company to do improvement at this stage of process.

Checking by manual calculation by using mathematical formulation

$$Cp = (USL - LSL) / 6\sigma$$

$$Cp = (1.510-1.424)/\ 6(0.0107242)$$
$$=1.34$$

$$Cpk = (USL - X)/\ 3\sigma \quad OR \quad (X - LSL)/\ 3\sigma$$
$$Cpk = (1.46583-1.424)/\ 3(0.0107242)$$
$$= 1.30$$

Both of Cp and Cpk values are in capable state.

CHAPTER 5

CONCLUSION

5.1 IINTRODUCTION

Process capability analysis reveals whether a process can meet product specifications and how effectively it can meet these specifications. It measures the amount of statistical control in a process. With process capability analysis, there are connection between the statistical control that have been set and the specification of the product.

According to this thesis, process capability analysis can be a powerful tool to predict the process capability in producing titanium dioxide (TiO_2) at Tioxide (M) Sdn Bhd. The process capability analysis had been successfully studied in Tioxide with a good collaboration between engineers and the human resources department. The process capability analysis studies required the understanding of the fundamental of process capability concept. Without a clear view on it, the case study will go to no point.

In this thesis, all the objectives had been achieved which are to access the current process capability, to predict future capability analysis of the process to produce product within the specification and to identify process improvement opportunity. The statistical process control (SPC) has chosen as a tool to perform the analysis. It must use SPC to define nonconformance (product out of specification), assist in eliminating them, and to define the process capability. By monitoring control chart, the state of process can be determined. Further, the chart can be

analyzed to help identify the root cause of problem, which is the first step toward problem elimination and prevention.

Process capability analysis had determined whether the process in control or out of the control. All the parameters control, which are Grey Stage Time (GST), Precipitation Recovery, Crystal Size & Crystal Size Distribution and Particle Size & Particle Size Distribution display a good result on the Cp and the Cpk value. The Cp and Cpk value is the benchmark to predict the state of every process that had been controlled.

From the Chapter 4, which is the result and discussion part, it showed that the Cp value for Grey Stage Time 3 and Grey Stage Time 4 did not meet the specification of Cp value which is must be more than 1.33 to claim as capable state. The Cp value for Grey Stage Time 1 (GST 1) is 1.25 and for Grey Stage Time 2 (GST 2) is 1.27. Both of these values are not capable and some improvement needs to be done in order to make the state capable. The other process shows a good performance regarding to the values of Cp and Cpk. It is an optional to the Tioxide (M) Sdn Bhd to make improvement on the selected process or maintaining a good performance on that process by using inspection and monitoring from time to time.

5.2 RECOMMENDATION

This is the last part in this chapter where it comes out with some recommendation or future works to improve the process in manufacturing titanium dioxide. Regarding to the results and discussion in chapter 4, it shown that process in Grey Stage Time 3 & Grey Stage Time 4 need some changes to increase the performance of the process. While observing and analyzing on the process, it has been discovered some recommendation to improve the process. The recommendations suggestion stated below:

- The temperature of simmering in the grey stage time process should be increase because it gives both faster growth rate of the solid species and increase the nucleation rate.

- Therefore, the rate of Grey Stage Time will increase and the transition color of pigment from black to grey will increase to due the reduction of Ferum. (more $Fe^{3+} \rightarrow Fe^{2+}$).
- The increasing of rate also affects the recovery of the process. Recovery process due to percentage of reduction of Fe^{3+} to Fe^{2+}.
- The specific gravity in the concentrator should be reducing in order to increase the rate of grey stage.

Finally, it is wish that the recommendation stated above would bring an improvement to the process manufacturing titanium dioxide (TiO_2) at Tioxide (M) Sdn Bhd and contributes some benefits to the industry. Furthermore, the recommendation would increase the productivity and lead to a good process capability in manufacturing process.

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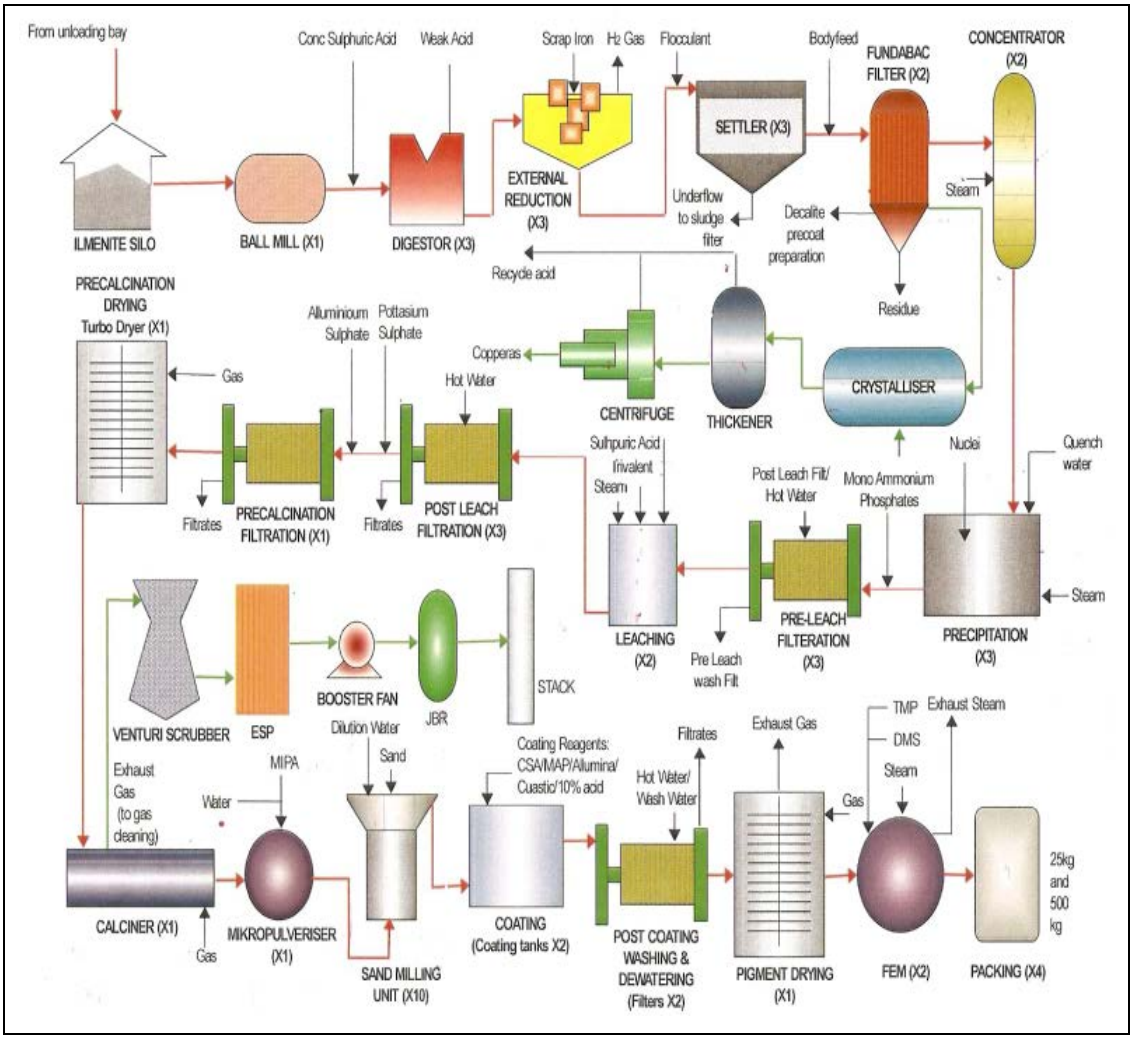
APPENDIX A



Process flow diagram in manufacturing titanium dioxide (TiO_2)

Appendix B

No	ACTIVITIES	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
1	Process start															
2	Project information															
	i) Project title															
	ii)Project objective															
	iii)Project scopes															
	iv)Project background															
3	Flowchart															
4	Submit project proposal															
5	Gantt chart															
6	Project methodology															
7	Literature Review															
8	Onsite visit															
9	Submit report															
10	Presentation															

Gantt chart for Final Year Project 1

Appendix C

No	ACTIVITIES	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
1	Onsite visit															
2	Collecting data															
3	Calculate control limits															
4	Capability study & process improvement															
5	Discussion															
6	Conclusion & recommendation															
7	Presentation															
8	Make correction															
9	Report writing															
10	Submit report															

Gantt Chart for Final Year Project 2