

ANALYSIS OF INDUSTRIAL PRODUCTION DATA USING STATISTICAL QUALITY CONTROL (SQC)

Submitted in partial fulfillment of the requirements for
the award of
Bachelor of science degree in Mathematics (B.sc Mathematics)

by

SETHUPATHY. K (38060009)



**DEPARTMENT OF MATHEMATICS
SCHOOL OF SCIENCE AND HUMANITIES**

**SATHYABAMA
INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)
Accredited with Grade "A" by NAAC
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APRIL – 2021



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BONA FIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **SETHUPATHY.K (38060009)** who carried out the project entitled "**Analysis of industrial production data using Statistical Quality Control** " under my supervision from **January 2021 to April 2021**.

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Submitted for Viva voce Examination held on_____

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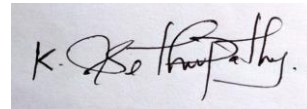
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DECLARATION

I **SETHUPATHY.K (38060009)** hereby declare that the Project Report entitled "**ANALYSIS OF INDUSTRIAL PRODUCTION DATA USING STATISTICAL QUALITY CONTROL**" done by me under the guidance of **DR. K.SHIVAKUMAR (INTERNAL)** and _____(External) at **SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY, RAGIV GANDHI SALAI, CHENNAI-600119** is submitted in partial fulfillment of the requirements for the award of Bachelor of Science degree in Mathematics.

Date: 26.3.2021

A rectangular box containing a handwritten signature in black ink. The signature appears to be 'K. Sethupathy' written in a cursive style.

PLACE: CHENNAI

SIGNATURE OF THE CANDIDATE

ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to Board of Management of SATHYABAMA for their kind encouragement in doing this project and for completing it successfully. I am grateful to them.

I convey my thanks Dr.M.Nirmala, Head of the Department, Department of Mathematics for providing me necessary support and details at the right time during the progressive reviews.

I would like to express my sincere and deep sense of gratitude to my Project Guide Dr.K.Shivakumar for his valuable guidance, suggestions and constant encouragement paved way for the successful completion of my project work.

I wish to express my thanks to the project coordinator Dr.K.Shivakumar all Teaching and Non-teaching staff members of the Department of Mathematics who were helpful in many ways for the completion of the project.

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ANALYSIS OF INDUSTRIAL PRODUCTION DATA USING STATISTICAL QUALITY CONTROL

ABSTRACT

The way in which businesses compete is rapidly changing. Businesses must constantly strive to offer “better” products and services than their competitors. Most of the Indian Companies on the whole need to improve the quality of their products in order to be a player in the global market. Managers must decide how to overcome the many problems that prevent quality products and services. One of the aims of this study is to know and also to establish whether managers in the Manufacturing industries are aware of the uses of statistics in decision making. In this study, it was found that most of the quality managers either do not use statistical quality control techniques or use them hardly ever. It was established that the majority of the respondents do not use statistical quality control charts. The above facts indicate the need for the awareness of the uses of statistical quality control techniques and charts to improve the quality of products and services

CHAPTER-1

INTRODUCTION

1.1. STATISTICAL QUALITY CONTROL (SQC):

Statistical Quality Control (SQC) is a scientific method to analyze manufacturing data. Based on this analysis, measures are taken to maintain the quality of the manufactured product. A control chart is the tool used to monitor the variation in a process and ensure that the process is in a state of control. This allows the operator to monitor the trends occurring in the process. The control chart reflects the specification limits, namely, the Upper Specification Limit (USL) and the Lower Specification Limit (LSL). In addition, it has upper and lower control limits that lie within the specification limits. The Upper Control Limit (UCL) and the Lower Control Limit (LCL) are determined by evaluating the dispersion (variability) in process, see Fig. 1. In a well-controlled process, these limits can be chosen to be equal to $\mu \pm 3\sigma$ respectively, where σ is the process standard deviation and μ is the process mean. These statistical limits are normally called the .3 sigma control limits..In a normal (Gaussian) distribution, 99.73% of the values measured lie in interval of width 6σ .

The production process cannot be separated from consumers and resulting product. Consumers certainly hope that the items they buy will be able to meet their needs and desires so that consumers hope that these products have right and guaranteed conditions. Therefore, companies need to maintain that the quality of the products produced are guaranteed and accepted by consumers and can compete in the market. Excellent quality will generate trust from consumers. Meanwhile the production must pay more attention to the quality of the products result therefore required quality control to find out whether the product defects produced are still within limits. As we know quality control in companies both service companies and manufacturing companies is essential. The production hopes to attract consumers and can meet the needs and desires of consumers with the quality of services or goods produced.

Quality control that is carried out correctly will have an impact on the quality of the resulting product. The quality of the products produced by production is determined based on specific characteristics. Although the production processes have been carried out well, in reality, there are still errors that the quality of the product produced is not following the standard, or in other words, the product is damaged or defective in the product.

The result of the excellent quality of the product comes from good quality control. Many companies use specialized methods to produce good-quality products. For this reason, the quality control necessary to keep the product generated by the applicable quality standards. The company's quality standards are usually dependent on raw materials, production process, and the finished product (results). Therefore, the activities of quality control can be done starting from the selection of materials, the production process up to the final result in the form of products and customized by the standards set in the company.

Statistical Process Control (SPC) is the process control tool that is commonly used, this tool is often used to find out the source of variations in the control chart along with the analysis of process capabilities. In many statistical applications, control chart has an important role to assess the "quality" of product; either in control or out of control (Lestari, 2015). Control Chart was first introduced by Dr. Walter Andrew Shewhart of Bell Telephone Laboratories, the United States, in 1924 intending to eliminate abnormal variations through separation of variations caused by the particular causes of variation and common causes. This variation means that the production process must be stable and capable of operating in such a way so that all products are produced according to specifications.

Quality requires an ongoing improvement process. Quality improvement can be appropriately made when the measured values are within the SPC approach expectations. The incompatibility of such quality characteristics and weight of the products will have an impact on the one hand, which the producer or the consumer. If the characteristics of the quality exceed the specifications of the manufacturer will be harmed, and if the characteristics under the specifications of the consumers will be harmed.

By the research problem described before, the writer can conclude that the objectives of the study to analyze quality control of bread using attributes P-chart to meet in quality control statistics

1.2. QUALITY CONTROL TOOLS:

Statistical process control aims to produce the products in the most economic and useful way by using statistical principles and techniques at every stage of the production. In this manner, statistical process control aims faithfulness to the standards, provides the fitness of the specifications that have been determined earlier. It is used to reduce the defected products as much as possible.

Statistical process control is powerful collection of problem-solving tools useful in achieving process stability and improving capability through the reduction of variability. The company had used some of the “seven basic quality control tools” in their problem solving technique. The seven quality tools are (Ishikawa, K. 1985). These tools, often called magnificent seven are;

- Check Sheet
- Pareto Chart
- Histogram
- Scatter Diagram
- Process Flow Chart
- Cause and Effect Diagram or Fish Bone Diagram

Control Chart

The control chart is perhaps the most widely used of the “seven basic quality control tools”. It is the key tools in statistic quality control because it displays process behavior graphically and it is used to monitor and control processes within the specified control limits. There are two basic types of control chart, depending on the type of data collected; namely variable control chart and attribute control chart. Variable control chart are designed to control product characteristics and process parameters which are measured in continuous scale.

The primary variable control chart used are the X-bar and R chart and moving range chart, while the other two, rarely used charts include X-bar and s chart and median chart.

Attribute control charts are designed to control the process. Measurements used are in terms of good or bad, accept or reject, go/no-go, or pass or fail criteria (e.g. conforming or nonconforming) The distinction between nonconforming or defective unit and nonconformities or defects is very important in attribute control chart because it will determine the selection in the type of attribute control chart used. A nonconforming or defective unit, however, may fail to meet the assessment criteria because of one or more nonconformities or defects exist. For attribute data, there are: p chart, np chart, c chart and u chart. The p and np charts are the most widely used. They are primarily used to monitor the fraction of nonconforming unit, while, the c and u charts are used to monitor the number of nonconformities or defects.

1.3. STATISTICAL PROCESS CONTROL (SPC)

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 process quality and maintain processes to fixed targets. 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 or service is being produced 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.

Acceptance sampling refers to the process of randomly inspecting a certain number of items from a lot or batch in order to decide whether to accept or reject the entire batch. What makes acceptance sampling different from statistical process control is that acceptance sampling is performed either before or after the process, rather than during the process.

Acceptance sampling before the process involves sampling materials received from a supplier, such as randomly inspecting crates of fruit that will be used in a restaurant, boxes of glass dishes that will be sold in a department store, or metal castings that will be used in a machine shop. Sampling after the process involves sampling finished items that are to be shipped either to a customer or to a distribution center. Examples include randomly testing a certain number of computers from a batch to make sure they meet operational requirements, and randomly inspecting snowboards to make sure that they are not defective.

Statistical Process Control (SPC) involves using statistical techniques to measure and analyse 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. SPC is used to monitor the consistency of processes used to manufacture a product. It aims to get and keep processes under control.

Statistical process control methods are applied to virtually any type of organization, including service, manufacturing, and educational organizations.

process is said to be in statistical control when all special causes of variation have been eliminated and only natural (or common) cause variation remains. On a control chart, this is illustrated by data that falls within control limits and by the absence of non-random patterns or trends.

Collecting and Recording Data

SPC data is collected in the form of measurements of a product dimension / feature or process instrumentation readings. The data is then recorded and tracked on various types of control charts, based on the type of data being collected. It is important that the correct type of chart is used gain value and obtain useful information. The data can be in the form of continuous variable data or attribute data. The data can also be collected and recorded as individual values or an average of a group of readings. Some general guidelines and examples are listed below. This list is not all inclusive and supplied only as a reference.

Variable data

- Individual – Moving Range chart: to be used if your data is individual values
- Xbar – R chart: to be used if you are recording data in sub-groups of 8 or less
- Xbar – S chart: to be used if your sub-group size is greater than 8

Attribute data

- P chart – For recording the number of defective parts in a group of parts
- U chart – For recording the number of defects in each part

1.4. CONTROL CHART

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.

One of the most widely used control charts for variable data is the X-bar and R chart. X-bar represents the average or “mean” value of the variable x . The X-bar chart displays the variation in the sample means or averages. The Range chart shows the variation within the subgroup. The range is simply the difference between the highest and lowest value. The following steps are required to build an X-bar and R chart:

- Designate the sample size “ n ”. Usually 4 or 5 are common sample sizes used in many industries. Remember the sample size should be 8 or less. Also determine the frequency that the sample measurements will be collected.
- Start collecting your initial set of samples. A general rule is to collect 100 measurements in groups of 4 which would result in 25 data points.
- Calculate the average value for each of the 25 groups of 4 samples.
- Calculate the range of each of the 25 samples of 4 measurements. The range is the difference between the highest and lowest value in each set of 4 sample measurements.
- Calculate X-bar (the average of the averages), which is represented on the X-bar chart by a solid centerline.
- Calculate the average of the sample ranges or “R” values. This will be the centerline of the Range chart.
- Calculate the Upper and Lower Control Limits (UCL, LCL) for each chart. To be clear, the control limits are not the spec limits set by the engineer on the drawing. The control limits are derived from the data. Most engineers utilize statistical software that will perform the calculations automatically.

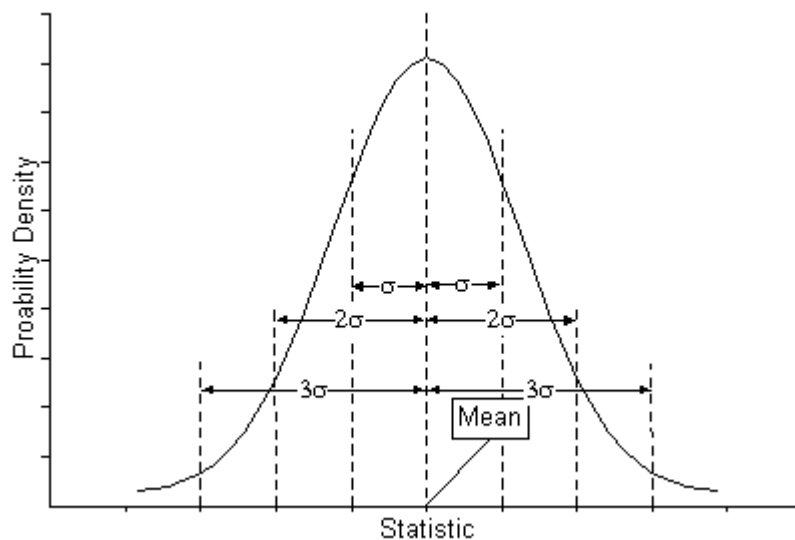
Once the chart is setup, the operator or technician will measure multiple samples, add the values together then calculate the average. This value is then recorded on a control chart or X-bar chart. The range of the subgroups is also recorded. The sample measurements should be taken and recorded in regular intervals, including date and time to track the stability of the process. Watch for any special or assignable causes and adjust the process as necessary to maintain a stable and in control process.

The X-bar and R chart is merely one example of the different control charts available for process monitoring and improvement. For assistance in determining the best practices to improve your processes, contact one of the many professionals at Quality-One.

Control charts make assumptions about the plotted statistic, namely

- ▶ it is independent, i.e. a value is not influenced by its past value and will not affect future values.

- ▶ It is normally distributed, i.e. the data has a normal probability density function (below)

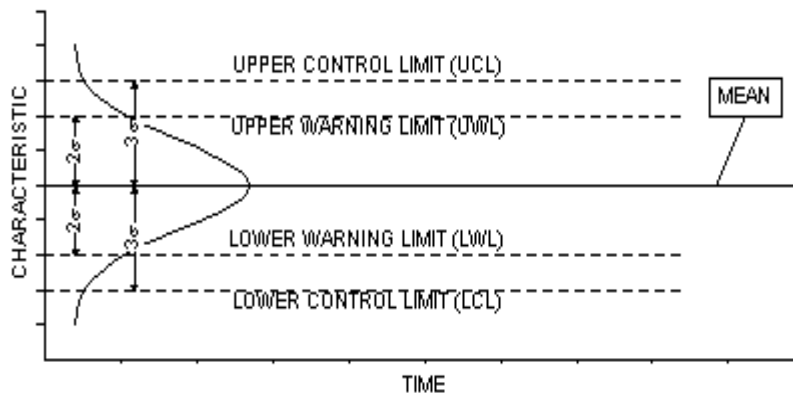


The normal distribution $N(m,s^2)$ has several distinct properties:

- The normal distribution is bell-shaped and is symmetric
- The mean, m , is located at the centre
- The probabilities that a point, x , lies a certain distance beyond the mean are:
 - $\Pr(x > m + 1.96s) = \Pr(x < m - 1.96s) = 0.025$
 - $\Pr(x > m + 3.09s) = \Pr(x < m - 3.09s) = 0.001$

where s is the standard deviation of the data

Control charts are normal distributions with an added time dimension. Below is a Shewhart X chart with control and warning limits:



The probability of a sample having a particular value is given by its location on the chart.

- the probability of a value lying beyond the warning limits is approximately 0.025 or 2.5% chance
- the probability of a value lying beyond the control limits is approximately 0.001 or 0.1% chance, this is rare and indicates that: (1) the variation is due to an assignable cause; (2) the process is out-of-statistical control

Run rules are rules that are used to indicate out-of-statistical control situations. Typical run rules for Shewhart X-charts with control and warning limits are:

- a point lying beyond the control limits
- 2 consecutive points lying beyond the warning limits ($0.025 \times 0.025 \times 100 = 0.06\%$ chance of occurring)
- 7 or more consecutive points lying on one side of the mean ($0.5^7 \times 100 = 0.8\%$ chance of occurring and indicates a shift in the mean of the process)
- 5 or 6 consecutive points going in the same direction (indicates a trend)
- Other run rules can be formulated using similar principles

Analyzing the Data

The data points recorded on a control chart should fall between the control limits, provided that only common causes and no special causes have been identified. Common causes will fall between the control limits whereas special causes are generally outliers or are outside of the control limits. For a process to be deemed in statistical control there should be no special causes in any of the charts. A process in control will have no special causes identified in it and the data should fall between the control limits. Some examples of common cause variation are as follows:

- Variation in material properties within specification
- Seasonal changes in ambient temperature or humidity
- Normal machine or tooling wear
- Variability in operator controlled settings
- Normal measurement variation

Adversely, special causes generally fall outside of the control limits or indicate a drastic change or shift in the process. Some examples of special cause variation are below:

- Failed controllers
- Improper equipment adjustments
- A change in the measurement system
- A process shift
- Machine malfunction
- Raw material properties out of design specifications
- Broken tool, punch, bit, etc.
- Inexperienced operator not familiar with process

When monitoring a process through SPC charts the inspector will verify that all data points are within control limits and watch for trends or sudden changes in the process. If any special causes of variation are identified, appropriate action should

be taken to determine the cause and implement corrective actions to return the process to a state of statistical control.

There are other variations or patterns of data points within the control limits that should also be tracked and investigated. These include but are not limited to:

- Runs where 7 or more data points are in a row on one side of the process centerline
- Changes in the normal spread of data, where multiple data points fall either farther apart or closer together
- Trends which are represented by 7 or more data points consistently raising or declining
- Shifts in the data spread above or below the normal mean.

CHAPTER-2

LITERATURE SURVEY

TITLE:

IMPLEMENTATION OF STATISTICAL QUALITY CONTROL (S.Q.C.) IN
WELDED STAINLESS STEEL PIPE MANUFACTURING INDUSTRY

AUTHOR; Kapil Banker, Amit Patel, Diptesh Pate.

Stainless steel welded pipe is manufacture by various methods like as shearing, bending, partial welding, full welding, nitriding, final length, expanding and buffing. This research is about to implement statistical quality control tools in pipe manufacturing industries. There are various defect found in stainless steel welded pipe manufacturing, due to these defects, pipes are rejected lot wise, and that is very unproductive result for each and every industries. Statistical quality control (SQC) tools, such as $\bar{x}$ bar chart, R-chart, C-chart, P-chart had been utilized to measure the variability in the process. We observed good result about the process, whether it is in control or not. These types of charts will also provide the fast result that will be used to take action immediately. In pipe manufacturing industries, rejection reduction is possible by proper shearing process, appropriate welding line, maintaining expanding process. This research helps to decide the process within the control limit or not, that would be decided by various control charts. This is also used for quality improvement. In S.Q.C, there are number of tools used such as Frequency distribution, Control charts, acceptance sampling, and analysis of the data. From all of these tools, we have to concentrate only on control charts. Ultimately, It has been used for any manufacturer to solve the rejection problem, enhancing the productivity and quality of the product. In purvey industries, out of control process has been detected by Xbar and R chart and root cause analysis used for defect detection. C chart has also been used for depicted the number of defects in the particular lot.

Using the C chart it can be easily decided whether the particular lots are accepted or not. Flow of this research is the beginning with the introduction,

Literature review regarding the research area then Methodology followed by the result and discussion. Finally future scope of the research is presented.

In "MACHINE TOOL CONDITION MONITORING USING STATISTICAL QUALITY CONTROL CHARTS by A. D. JENNINGS and P. R. DRAKE" have focused on the application of control chart to monitoring the machine tool performance parameters. They developed the effective maintenance system by setting arbitrarily alarm with the control limits. When the process being out of control the alarm automatically rung and operator can understand there are some problem in machine.

They used V4-6 CNC vertical milling machine for recording various data. They also developed control chart for diagnosis the problem of machine tool parameter. While the determination of problem for machine maintenance, they focused on one, two and three variable for depicted the control chart. Ultimately they conceded that the control charts have been introduced for monitoring of machine tool parameter. In "Statistical process control in machining, a case study for machine tool capability and process capability" by Ali Rıza Motorcu, Abdulkadir. They focused on statistical process control method to eliminate the quality problems such as undesirable tolerance limits, circularity of spheroidal cast iron parts during machining. At the stage of study they observed that some parts were oval and out of tolerance limit, machines and processes were insufficient and production was instable.

The data had been gathered and through the analysis of data some assignable cause for faulty work pieces were discovered. In addition to these developments, surface roughness and circularity of work pieces were improved. They concluded that, the production had not carried on normally before the statistical work. After the statistical study, during the machining the sizes having quality problems the production lines where parts were manufactured out of tolerance were determined. It was detected that the machine tool and process capability for the whole process was inadequate and the mass production was unstable. Ovality, faults regarding manufacturing out of tolerance limits were eliminated and surface

roughness was improved. As a result of their study, the employee understood the quality requirement, the cost due to inequality production was reduced and the production was enabled to carry on normally with the help of problem solving desire of them. Since this study reduced the inequality costs during production, the company management supported the study. However, because of economic problems.

In "Quality estimation of process with usage control charts type X-R and quality capability of process C_p , C_{pk} " by M. Dudek-Burlikowska has focused on statistical quality control method to resolve the problem of process capability. He used the X-R chart for process capabilities and concluded that Usage of quality research and estimation methods in Polish industry permits to avoid occurrences of productive defects already in production stage, which helps in elimination of their source formation. The most popular method used in quality assurance systems for productive process is statistical process control. SPC involves using statistical techniques to measure and analyze the variation of the process. Most often used for manufacturing processes, the intent of SPC is to monitor product quality and maintain processes to a fixed target.

He concluded that the aim of usage of control charts type X-R in above process was to measure and minimize the variations that occurs in the process, and the essential aspect was delimitation of coefficients of process correctness that leads to improvement. He was also found that from the investigational processes that usage of quality statistic methods was a good factor which permits to qualify, when emerging problems can be solved locally, and when the collective decision of the management is necessary.

In "statistical process control for the process industries" by John A. Shaw has focused on statistical quality control chart. He observed that process is out of control when $\bar{X}$ values reached beyond control limits. He also observed that an important part of the X chart is the sub grouping of four to five measurements that are averaged to provide one point on the chart.

The concept is that the natural inherent variation will be reflected in the average range of the subgroup, while the difference between one subgroup and another will; if it is greater than a certain amount, and reflect the assignable cause.

He was also introduced a alarm system for process industries. As per his observation one application of SPC is to produce alarms when the measured variable is out of statistical control. He concluded that Statistical process control has served as an important tool in the discrete parts manufacturing industries to improve product quality, reduce variability, and decrease cost. It is being adopted by many companies in the chemical process industries, in part due to pressure from their customers. In some areas within the chemical industry, SPC has proven to be a useful and successful tool. Its applicability must be examined in all areas of the chemical industry, application by application. Two primary considerations should govern its acceptance for each individual application: the ability of SPC to produce meaningful results, and the need for SPC as compared to other statistical and non statistical tools.

Khong sak Srikaeo et.al (2004) analyzed in their paper that the association between raw material variables and product variables. They adopted SPC techniques such as histogram to found that the data were not normally distributed ANOM detect a association between the production line from the grand mean in all product variables, p-control charts showed that the process is not in statistical control for some variables. Since they use the historical data the out of control points where removed to simulate the situation where the process is in statistical control for further studies. With the process can capability studies the process precision and accuracy can be clearly assessed. Gauge R and R studies suggest that the variations found in the process are caused by the measurement system used in the plant.

Nigel P.Grigge et.al (1998) presented a case study that the use of statistical process control in fish product packaging in the year 1498 which demonstrated the simplicity of applications of the off-the peg system. Such system can reduce unnecessary check weighs rejections and product give away, assist the packer to maintain the lowest possible legal target quantity.

Andras Ittzes (2000) in his paper evaluated that the application of SPC is that of the several variance components of the variable in the control of the dry matter content in butter cream. He evaluated the data of Analysis of Variance (ANOVA) based on the nested model. He also referred Snedecor and Cochran (1967) or Steiner (1984).

Ali Mostafaeipour et.al (2012) in their paper introduced that SPC technique in ceramic tile manufacturing plant. They suggested SPC for reducing the unwanted ceramic tile defects and wastages. They adopted pareto chart to group different causes for inappropriate effects and its category. Also they adopted six-pack charts to offer six different packs in the format of one diagram. They applied control chart like R, $\bar{X}$ and range control charts to manage the process variations. They also adopted dispersion diagram to evaluate and to compare process performances during various periods. Data are categorised in a specific format by using Histogram. Also process capability is one of the significant items in production. Finally they recommended complementing the correct SPC frequently in the manufacturing plant to minimise ceramic tile waste.

Ranjit Sabhapandit et. al (2014) in their paper described about some of the software tools and their capabilities that are used for applying SPC techniques. They also suggested the need for applying statistical process control in software development process. They discussed about few most repetitively applied software tools such as WinSPC, Zontec, XLSTAT, SCADA and Minitab. They sternly said that the organization has to opt the proper tool that suit best to its needs in order to have the most effective output.

Yonatan Mengesha Awaj et. al (2013) recommended to pertain the SPC tools in the production processing in order to condense defects by identifying where the highest waste is occur at and to give idea for improvement. They adopted, Pareto chart/analysis and control chart (p-chart). They mainly explained how to create consciousness to quality team how to use SPC tools in the problem analysis, particularly to train quality group on how to held an successful brainstorming session, and make use of these data in cause-and-effect diagram construction, Pareto analysis and control chart construction. After detail observation and interview they suggested that SPC tools needed to minimize or reduce the problem and the more

proficient technique is long run. Finally he sturdily recommended that the company should make every effort for the implementation of SPC tools for productivity improvement.

Ved Parkash et.al (2013) described about the SPC, its advantages, limitation, applications and information regarding the control charts. They also introduced the primary groups of input for man, machine, material, method and milieu. They explained the application of SPC into three main sets of activities, the first understands the process and is achieved by business process mapping, the second is measuring the sources of variation assisted by the use of control charts and the third is eliminating assignable (special) sources of variation. They suggested SPC, can be used in various industries for improving the quality of the product and helps in lowering the product costs as it provides a better product and/or service.

Rami Hikmat Fouad et.al (2010) in their paper identified the key ingredients for successful quality management in any industrial organization. They also illustrated how is it important to realize the intergradations between SPC are seven tools, and how to effectively implement and to earn the full strength of these tools. They also carried out a case study to monitor real life data in a Jordanian manufacturing company that specialized in producing steel and found that the steel tensile strength is the vital few problem and account for 72% of the total results of the problems. They specified the major causes of nonconformities and root causes of the quality problems and possible remedies were also proposed.

They also explained the necessity of SPC tools in Jordan Steel to introduce ongoing education and training programs of management and line staff.

Rallabandi Srinivasu et. al (2011) recognized (SPC) as effective approaches for process monitoring and diagnosis. They suggested that SPC principals and techniques would be at every stage of the production and to control quality characteristics on the methods, machine, goods, equipments both for the company and operators with magnificent seven. He explained the “seven basic quality control tools” which provide a very valuable and cost effective way to meet the objectives.

Dr. D. R. Prajapati (2012) adopted some SPC techniques in the industry for various applications in the automotive industry. He explained the power of SPC lies

in the ability to examine a process and the sources of variation in the process. He used only two main techniques i.e. cause and effect diagram and control charts are implemented in industry out of seven SPC techniques. Finally he found in his case study that after implementing the SPC tools to remove the root causes, the percentage refutation is reduced from 9.1% to 5% and process capability of 0.953 is achieved.

Muhammad Riaz et. al (2012) strongly recommended that the control charts worth in the manufacturing industry. They also suggested that monitoring the key characteristics is most important in any manufacturing industry. They strongly believed that the inefficient of a quality control section may cause poor quality of a product.

Ben Mason and Jiju Antony (2000) in their paper discussed the ingredients that are needed for the victorious performance of SPC. They attempt to eradicate the myth that SPC is concerned with only the control charting of processes. A major issue addressed by them in this paper is the need for the organized and realistic methodology for the execution of SPC in industry.

Gasper Skulj et.al (2013) in their Illustrated a service approach of SPC and discussed through an industrial case study. They clearly explained the successful development and implementation of SPC as a service. They also discussed how to use the SPC service in a small company to increase its capabilities in process quality management and process control through a case study.

Zhonghua li et. al (2012) in their paper designed Conventional Phase II SPC charts using control limits. They suggested designing the SPC charts using p values. They demonstrated the p value approach to consider univariate process monitoring by cumulative sum control charts in various cases. They also proposed designing control charts using p values and a significance level.

Erwin M. Saniga (1989) explained the control charts which may be designed by using a simple rule recommended by Shewhart, by a statistical norm, or by an financially viable criterion. He placed statistical constraints on economic models to provide designs that meet industry's demand for low-process variability and long-term product quality. He illustrated its use in the joint design of an X bar chart and an R chart. He developed a method to find the most economical statistical design for Shewhart-type control charts and have applied it to the joint determination of the parameters of X bar chart and R charts.

CHAPTER-3

AIM AND SCOPE OF THE PRESENT INVESTIGATION

3.1. AIM:

The project deals with application of Statistical Quality Control the Calibration of oil storage tanks

The main objective of SQC is the systematic reduction of the variance of any relevant quality characteristic. The most usual statistical techniques in of quality are acceptance sampling, Statistical Process Control (SPC), regression analysis, analysis of variance, time-series analysis, reliability, and experimental design[Taguchi's designs. The typical evolution in the use of statistical techniques in SQC can be summarized in the following way:

(1) At the lowest level of maturity, there exist only modest applications of acceptance sampling;

(2) When maturity increases, sampling inspection is intensified;

(3) Next comes SPC, with the systematic use of control charts, already developed by others;

(4) When the process attains stability and maturity increases, it is then usual to develop different experimental designs and to assess the reliability of the final product. This enables the improvement and optimization of production.

Calibration of storage tanks is an exact means of determining the accurate capacity of storage tanks at a given incremental level. When calibrating a certain number of oil storage tanks having the same dimensions, it is assumed that if the specified tank dimensions are within the statistical control limits, a calibration chart generated for one tank can be used for the other tanks. This study used X-bar and R-control chart to investigate the stability of the tank calibration process for some fabricated oil storage tanks. The method of control chart was used to check if the process is under control or not.

The variables of the calibration process are Circumference of each course shell, Height of each course shell and Elevations for the bottom profile. Results revealed that the calibration process was statistically stable and under control with

no special or assignable cause of variation. Process capability conducted also showed that the calibrated tanks met the pre-set limits

3.2. SCOPE OF THE PRESENT INVESTIGATION

The scope of the research is to overcome defects through the statistical quality control method. The main concentration of this research is to overcome quality problem. These results can be used for calibration oil storage tanks also.

3.3 INVESTIGATION:

We begin with a brief historical introduction. First, and immediately after the Industrial Revolution only inspection was usual, to identify defective products and prevent their sale to consumers. Next, the use of SPC was intensified. In 1924, at the Bell Laboratories, Shewhart developed the concept of control chart, and, more generally, SPC, with the introduction of the statistical control chart, the so-called Shewhart-chart, shifting then the attention from the product to the production process (Shewhart, 1931). Dodge and Romig (1959), also in the Bell Laboratories, introduced and developed the sampling inspection, as an alternative to the 100% inspection.

Other pioneers were W.E. Deming, J.M. Juran, P.B. Crosby and K. Ishikawa. But it was during the Second World War that there was a generalized use and acceptance of SQC, mainly in the industries of manufacture. SQC was then largely used in USA and considered as primordial for the defeat of Japan. In 1946, the American Society for Quality Control was founded, and this enabled a huge push to the generalization and improvement of SQC methods. After the II World War, Japan was confronted with rare food and lodging, and the factories were in ruin.

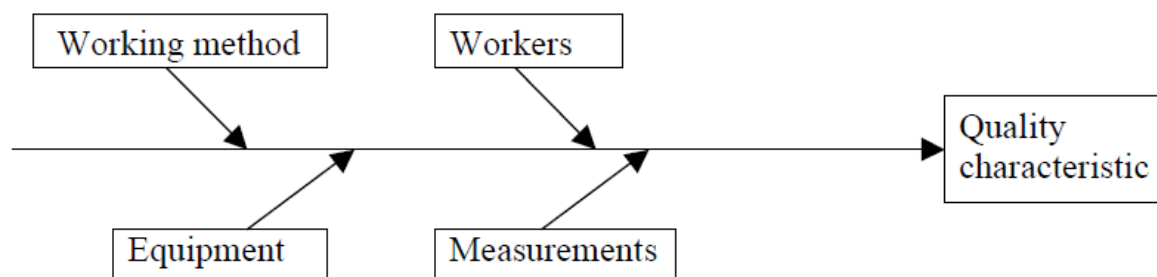
They evaluated and corrected the causes of such a defeat. The quality of the products was an area where USA had definitely overpassed Japan, and this was one of the items they tried to correct, becoming rapidly masters in inspection sampling and SQC, and leaders of quality around 1970. More recently, the efforts in quality development, which were initially centered in goods manufactured or consumed products were expanded to include services work developed for the benefice of others. Recently, the quality developments have also been devoted to the motivation

of workers, a key element in the expansion of the Japanese industry and economy. Quality is more and more the prime decision factor in the consumer preferences, and quality is often pointed out as the key factor for the success of organizations.

The implementation of a production QC clearly leads to a reduction in the manufacturing costs, and the money spent with control is almost irrelevant. At the moment, the quality improvement in all areas of an organization, a philosophy known as Total Quality Management (TQM) is considered crucial (see Vardeman and Jobe, 1999).

The challenges are obviously difficult. But the modern SQC methods surely provide a basis for a positive answer to these challenges. SQC is at this moment much more than a set of statistical instruments. It is a global way of thinking of workers in an organization, with the objective of making things right at the first place. This is mainly achieved through the systematic reduction of the variance of relevant quality characteristics.

SQC is nowadays routinely used in big organizations, which apart from their specific quality departments have contracts with researchers, who facilitate the development of simple but more sophisticated procedures to assure a better quality of their products. Among the large variety of simple instruments that promote quality, we first mention the cause-and-effect or fish-and-bone diagrams: If we want to achieve a certain objective, or if we have in mind a certain quality problem, all possible factors that lead to such an objective or such a problem need to be schematized in a scheme of the type:



CHAPTER-4

MATERIALS AND METHOD

4.1. INTRODUCTION:

Statistical Process Control (SPC) is a problem-solving technique that is used as a monitor, controller, analyzer, manager and improves the process using statistical methods. Philosophy on the concept of statistical process quality control or better known as statistical process control (Statistical Process Control) is the output of a process or service can be expressed in statistical control through management tools and design actions. Statistical process control is the application of statistical methods for measurement and analysis of process variation. This technique is the parameters of the process and process analysis.

The goal of statistical process control is primarily to reduce variation or process errors. The primary objective in statistical process control is to detect assignable cause or special cause in variations or process errors through data analysis from the future or the future as well. The process variation consists of two kinds of reasons, namely the common purpose that has been attached to the process, and assignable cause or special cause which is an excessive error. Ideally, only general reasons are shown or appear in the process, because it shows that the process is in a stable and predictable condition.

This condition shows minimum variation which defined as the non-uniformity of the product or service produced. Differences can also be defined as the product or service produced does not meet the standard specifications that have been set. Variations are grouped into two types:

1. Controllable Variation Controllable variations are variations that can be controlled or variations that can be removed or minimized if repairs are carried out. This type of variation is usually stable, consistent, likely random, predictable, naturally occurring,

inherent, random causes. Examples of this type of variation are less like raw materials, less careful operators, and others.

2. Uncontrollable Variations Uncontrolled variations are uncontrollable variations. This type of variation is usually unstable, inconsistent, unpredictable, and generally occurs due to natural or environmental factors, causing system abnormalities and can be repaired locally. Examples of this type of variation are air humidity, changing room temperature, changes in voltage, etc.

The control chart is a graph used to study how a process changes over time. Data are plotted in time order. A control chart always has a central line for the average, an upper line for the upper control limit and a lower line for the lower control limit. These lines are determined from historical data. By comparing current data to these lines, you can draw conclusions about whether the process variation is consistent (in control) or is unpredictable (out of control, affected by special causes of variation).

Calibration of storage tanks is an exact means of determining the accurate capacity of storage tanks at a given incremental level [1]. It is essential to accurately determine the quantity of product going in and coming out of the storage tanks for proper inventory control. Crude oil and its refined products are precious fluids owing to their market value and therefore cannot be sold above the expected measured quantity to the customers and also cannot be bought below the expected quantity from the suppliers. Various geometrical methods of tank calibration such as Manual Strapping Method (MSM), Optical Reference Line Method (ORLM), Optical Triangulation Method (OTM), and Electro-Optical Distance Ranging Method (EODRM) had been identified and discussed by [2] and [3].

In Nigeria, the most applicable geometrical method that is prevalently used for storage tank calibration is Manual Strapping Method [3]. The required field data that must be accurately determined while using MSM are Circumference of each Course Shell, Height of Each Course, and Elevations for the Bottom geometry/profile [4] [5]. Experimental research is considered necessary for a group of storage tanks (uniform dimensions) fabricated by the same company but for different clients. This is to see if

the aforementioned required field data (Circumference, Height, Elevations of bottom) are within the statistical control limit in order to check whether the calibration chart generated for one of the tanks in the group can be used for the others.

Though X-bar and R-chart and Xbar and S-chart are variable charts for sub-group; however, X-bar and R-chart was chosen as the most preferred Statistical Quality Control Chart (SQCC) for this study because data sub-group was less than eight (8) and also because only few works had been done using it. Tank calibration process involves adequate planning and scheduling as proper scheduling saves time and minimizes cost [6].

Hence, each of the above identified variable data are properly scheduled to obtain optimal output. The quality control analysis of any product is determined by its conformity with the standard set dimensions [7]. Statistical quality control uses different dimensions to evaluate the quality of products. The said dimensions could be conformance to the set limits, maintainability, serviceability, availability and durability [8]. [9] improved on the works of [10] and [11] by going beyond the design and application of Cumulative Sum (Cum-Sum) control chart but stated when to use it with much emphasis on practical problems as regards to monitoring changes in the parameters. [12] applied X-bar and S charts to investigate process stability in Electric Wire Industry and was able to show that that the production process was in statistical process control with respect to the diameter and electrical resistance of the without any assignable cause of variation. [13] used statistical calculations to eliminate quality problems such as undesirable tolerance limits and out of circularity of spheroidal cast iron parts during machining. X-bar and R control charts was constructed based on the data obtained from this manufacturing to detect and eliminate assignable causes, so that the machine capability (C_p) and the process capability (C_{pk}) can be ascertained.

In order to compare design tolerance on working drawings and attained tolerances on work pieces after machining five mass production lines were set up in a medium sized company. The results obtained from five X–R control charts and the data gathered from all production lines were processed and evaluated. At this stage

of the study, it was observed that some parts were oval and out of tolerance limits, machines and processes were insufficient and production was unstable. Through follow up studies on machine data, some assignable causes for faulty work pieces were discovered, and ovalness and out of tolerance limits errors were corrected.

Their findings showed that in small or medium sized companies, statistical quality control can be useful component of production provided that sufficient finance and qualified personal are used.

Pattern recognition techniques have been widely applied to identify unnatural patterns in control charts [14]. [14] presented a control chart pattern recognition system using a statistical correlation coefficient method. Most of them are capable of recognizing a single unnatural pattern for different abnormal types. However, before an unnatural pattern occurs, a change point from normal to abnormal may appear at any point in control charts for most practical cases. Moreover, concurrent patterns where two unnatural patterns simultaneously exist may also occur in a control chart pattern recognition system.

They concluded by confirming that statistical correlation coefficient approach is a simple mechanism for recognizing these unnatural control chart patterns with good performance. Cumulative Sum (CUSUM) chart, one of the Statistical Process Control (SPC) techniques, is a powerful tool in monitoring emissions data so that abnormal changes can be detected in a timely manner, using process capability indices to evaluate environmental performance in terms of the risk of non-compliance situations arising [15].

It explores how process capability indices have the potential to be useful as a risk management tool for practitioners and to help regulators execute and prioritize their enforcement efforts. [16] used X-bar and R Control chart in manufacturing industry to enhance productivity while minimizing defective products, thereby solving rejection problem. They used Apurvi Industries in India as a case study, out of control process was detected by X-bar and R chart and the root cause analysis was performed on the defective KSB Pumps.

One of the Calibration Companies in Nigeria, Concise Engineering & Technical Services Limited who has calibrated more than 90% of the tank fabricated by DeltaWeld Engineering Limited was consulted to get some of the field data. In 2015, DeltaWeld was awarded a contract of fabricating 15Nos Oil storage tanks by Alluvial Oil in its new depot. Calibration of the said tanks was subsequently given to Concise Engineering.

The method of calibration employed by Concise Engineering was MSM which involves accurate measurement of circumference by winding a strapping tape round each course shell. Pocket tape was used to determine the height of each course while the Leveling instrument was used to obtain the Elevations for the bottom profile. The measured field data for each fabricated tank was collected and checked if they are within the statistical control limit using X-bar and R control chart. Available data revealed that each tank has five (5) course shells with an average capacity of 1,500,000 litres. Hence, the work aimed at using the X-bar and Rchart in determining the stability and capability of calibration process for same set of oil tanks.

4.2. METHODOLOGY

The method to carry out the statistical quality control work will be as follows-

- 1) The test performance data was collected by a construction company which is a contracting firm specialized in RCC work of building.
- 2) From individual sites the data was collected in form of stock register entries for cement, river sand, and coarse aggregates received on site, the test record register for the raw materials, the quality check list before concreting, pour card before concreting and pour card after concreting, quality tests in form of N.D.T. to test the quality of concrete, the quality standards as per set by the consultants as per IS Code for concrete.
- 3) The data was collected from three different sites in progress simultaneously by the same having the topographical and environmental variations may be there.
- 4) The data collected was carefully studied and segregated as per statistical quality check requirement and was arranged in tabular table method form (frequency distribution method) and was carefully analyzed.

- 5) The computer program was prepared in MATLAB in which the various control charts are easily displayed selecting the suitable acceptance sampling number and the data in form of variance and 3σ values.
- 6) The standard deviation and the variance were calculated by tabular form method.
- 7) The result was tabulated and plotted on X-chart and R-charts graphs for each individual site for the same construction company and comparative statement was prepared by selecting suitable acceptance sampling number.

4.3. Mathematical Model:

The mean, $\bar{X}$ is a measure of central tendency of a group of measurements. Mathematically:

$$\bar{X} = \sum Xi/n$$

Xi = Individual observations and

n = Number of observations in a group.

The standard deviation σ (sigma) is a measure of the dispersion of the measurements from their mean. The mathematical definition is:

$$\sigma = \sqrt{\frac{\sum (Xi - \bar{X})^2}{n-1}} \quad \text{where, } Xi, \bar{X} \text{ and } n \text{ as above.}$$

The

variance (V), is the square of the standard deviation, mathematically

The standard error (σ_x) is the standard deviation of mean of several samples and is estimated by:

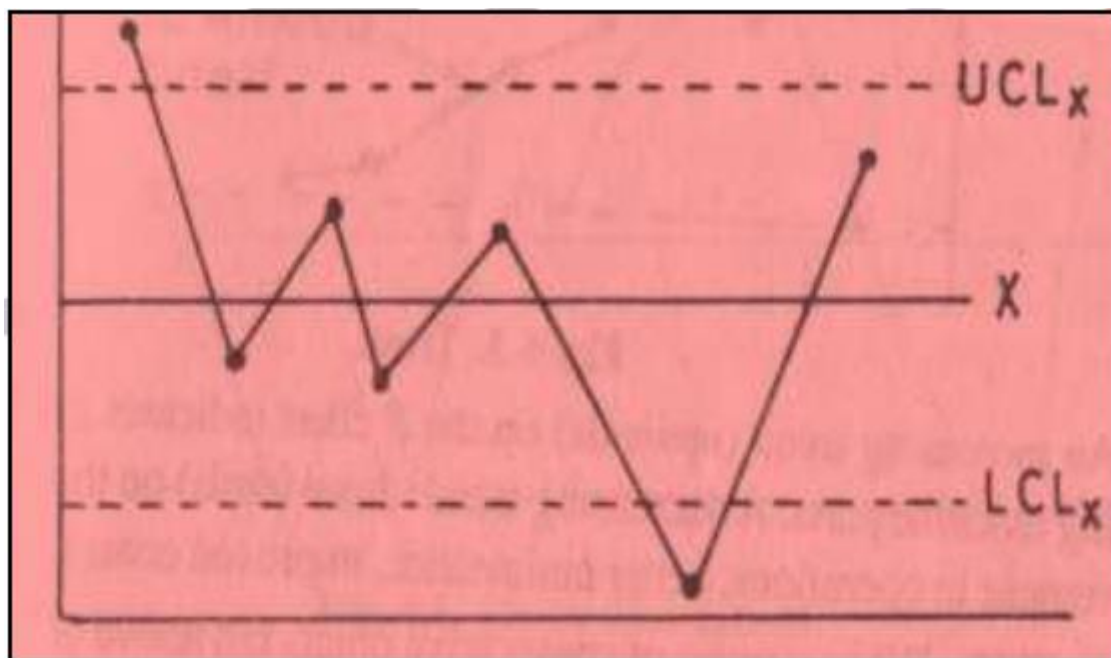
$$\sigma'_x = \sigma / \sqrt{n}$$

4.4. CONTROL CHARTS

Control of any repetitive process such as production of Portland cement concrete or bituminous hot mix is of prime importance. A control chart is a statistical tool, which gives a visual indication of the state of control of any production process. It is an instrument to be used in specification, production and inspection and

4.5. Objectives of Control Charts –

- 1) X-charts and R-charts are used in combination for the control process. X-charts shows the variation in the averages of samples. R-chart shows the variation s in the ranges of samples.
- 2) The control charts are used to determine whether a given process can meet the existing specifications without a fundamental change in the production process. when so used, brings these three phases of industry into an interdependent whole.



4.6. MATERIALS AND METHODS

Related data needed for the calibration were obtained directly from the field engineer. The data include: 1.) Circumference of each course, 2.) Height of Course Shells, and 3.) Elevations of the Bottom profile. Plate thicknesses for each course shell were not considered because they were all new tanks. Each of the above-mentioned data was analyzed using Minitab 17. X-bar charts were first drawn followed by R-charts but the analysis for the stability of tank calibration process started from R-chart using “Run rules”. If the R-charts indicate that the calibration process is stable, we then proceed to X-bar charts to further confirm the process stability. If both conditions for stability were met, then the next step was to check if the calibrated tanks were within the predefined specifications/limits.

The predefined limits for the Circumference, Height of Course Shell and Elevations of the Bottom profile are $\pm 30\text{mm}$, $\pm 20\text{mm}$ and $\pm 10\text{mm}$ respectively. It is not only enough to confirm the stability of the calibration process but there is also need to find out if the products (fabricated tanks) were within the specified limit. Process Capability was employed to check if the products are within the preset limits. Strapping tape (Figure 1) was used for measuring the circumference of each course shell by winding firmly round the tank shell. Pocket tape (Figure 2) and leveling instrument (Figure 3) were used to measure the Course shell height and elevation for bottom profile respectively.

4.7. X-bar and R-Control Charts:

X-bar and R-Control Charts is one of the Statistical Process Control (SPC) methods used for monitoring and improving a company's quality and productivity. X-bar chart is used to monitor the average value of a process over time. For each subgroup, the x-bar value is plotted. The upper and lower control limits define the range of inherent variation in the subgroup means when the process is in control. R-Chart on the other hand is a control chart that is used to monitor process variation when the variable of interest is a quantitative measure. These charts give deviations from desired limits within the quality process and, in effect, allow the company to make necessary adjustments to improve quality.

The following are the steps for constructing X-bar and R-charts.

- i. Collection and entering of the data into sub-group
- ii. Determination of the Average of each subgroup;

$$\bar{X} = \frac{X_1 + X_2 + X_3 \dots\dots X_n}{n} \quad (1)$$

- iii. Calculate the grand mean $\bar{\bar{X}}$ of the sub-group's average. The grand mean of the subgroup's average becomes the centerline for the upper plot.
- iv. Determine the Range R of each sub-group by subtracting lowest value from the highest value in the sub-group. Range = Highest-Lowest

(3)

- v. Calculate average of subgroup Ranges

$$\bar{R} = \frac{R_1 + R_2 + R_3 \dots\dots R_n}{k} \quad (4)$$

- vi. Determine the Upper Control Limit UCL and Lower Control Limit LCL for subgroup averages.

For X-bar chart:

$$UCL_{\bar{X}} = \bar{\bar{X}} + A_2 \bar{R} \quad (5)$$

$$LCL_{\bar{X}} = \bar{\bar{X}} - A_2 \bar{R} \quad (6)$$

For R-chart:

$$UCL_{\bar{R}} = D_4 \bar{R} \quad (7)$$

$$LCL_{\bar{R}} = D_3 \bar{R} \quad (8)$$

CHAPTER-5

RESULTS AND DISCUSSION

5.1. RESULTS

The measured field data as entered into sub-group, the mean as well as the range for the Circumference of Course shells, Height of Course shells and Elevations for Bottom Profile were presented in Table 1, Table 2 and Table 3 respectively.

Tank	C ₁	C ₂	C ₃	C ₄	C ₅	Average	Range
1	56050	56046	56061	56063	56055	56055	17
2	56055	56062	56071	56063	56064	56063	16
3	56061	56058	56056	56056	56051	56056.4	10
4	56065	56063	56064	56066	56058	56063.2	8
5	56058	56062	56062	56065	56050	56059.4	15
6	56063	56064	56064	56061	56053	56061	11
7	56061	56058	56056	56050	56046	56054.2	15
8	56065	56063	56064	56070	56058	56064	12
9	56061	56063	56055	56072	56063	56062.8	17
10	56069	56063	56064	56056	56056	56061.6	13
11	56064	56072	56063	56062	56062	56064.6	10
12	56061	56071	56056	56066	56065	56063.8	15
13	56063	56058	56063	56064	56050	56059.6	14
14	56060	56061	56061	56053	56050	56057	11
15	56053	56050	56058	56062	56062	56057	12

Table 1. Samples Circumference of Course Shells

Grand mean $\bar{X} = 56060.17$, Average Range $UCL_{\bar{R}} = 27.63$, $LCL_{\bar{R}} = 0$
 $\bar{R} = 13.07$, $UCL_{\bar{X}} = 56067.71$, $LCL_{\bar{X}} = 56052.64$,

Tank	H ₁	H ₂	H ₃	H ₄	H ₅	Average	Range
1	1200	1211	1209	1207	1207	1206.8	11
2	1202	1200	1208	1215	1212	1207.4	15
3	1195	1199	1203	1205	1204	1201.2	10
4	1207	1201	1198	1199	1201	1201.2	9
5	1210	1205	1206	1208	1202	1206.2	8
6	1206	1200	1201	1198	1195	1200	11
7	1205	1200	1195	1192	1207	1199.8	15
8	1204	1201	1193	1198	1205	1200.2	12
9	1205	1200	1203	1199	1196	1200.6	9
10	1197	1201	1206	1210	1209	1204.6	13
11	1198	1199	1208	1200	1201	1201.2	10
12	1203	1201	1193	1205	1204	1201.2	12
13	1205	1206	1208	1205	1200	1204.8	8
14	1207	1207	1193	1199	1203	1201.8	14
15	1209	1207	1193	1198	1205	1202.4	16

Table 2. Samples Height of Course Shells

Using equation 3 through equation 8, the following information were obtained from Table 2 which were used to construct X-bar and R-chart in Figure 5.

Grand mean $\bar{X} = 1202.63$, Average Range $\bar{R} = 11.53$, $UCL_{\bar{X}} = 1209.28$, $LCL_{\bar{X}} = 1195.97$,
 $UCL_{\bar{R}} = 24.39$, $LCL_{\bar{R}} = 0$

Using equation 3 through equation 8, the following information were obtained from Table 3 which were used to construct X-bar and R-chart in Figure 6.

$$\begin{aligned} \text{Grand mean } \bar{\bar{X}} &= 117.2, \text{ Average Range } \bar{R} \\ &= 4.067, \quad UCL_{\bar{X}} = 119.546, \quad LCL_{\bar{X}} = 114.854, \\ UCL_{\bar{R}} &= 8.54, \quad LCL_{\bar{R}} = 0 \end{aligned}$$

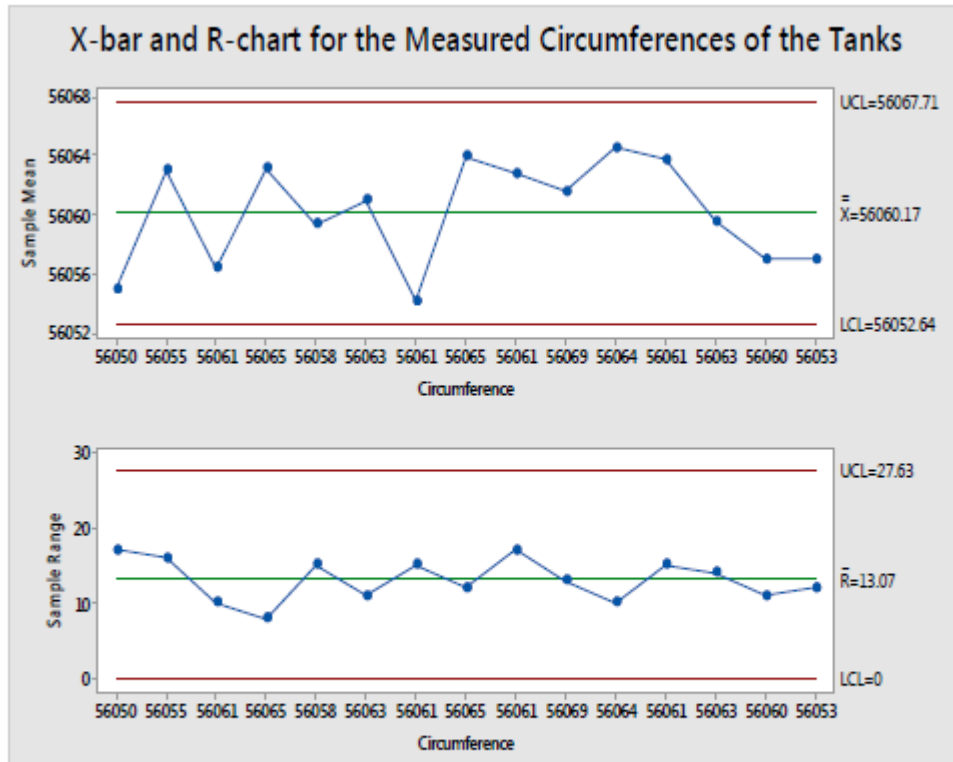


Fig. 4. X-bar and R-chart for the Samples Circumference

Tank	E ₁	E ₂	E ₃	E ₄	E ₅	Average	Range
1	119	118	116	117	115	117	4
2	120	119	115	116	117	117.4	5
3	116	118	119	116	115	116.8	4
4	120	119	118	116	117	118	4
5	116	116	115	117	116	116	2
6	118	118	117	115	116	116.8	3
7	118	117	119	117	116	117.4	3
8	115	117	118	119	120	117.8	5
9	119	117	118	116	115	117	4
10	118	116	120	119	115	117.6	5
11	114	117	116	118	115	116	4
12	117	119	120	118	116	118	4
13	115	117	119	120	118	117.8	5
14	115	117	116	119	117	116.8	4
15	115	120	118	116	119	117.6	5

Table 3. Samples Elevation for the Bottom Profile

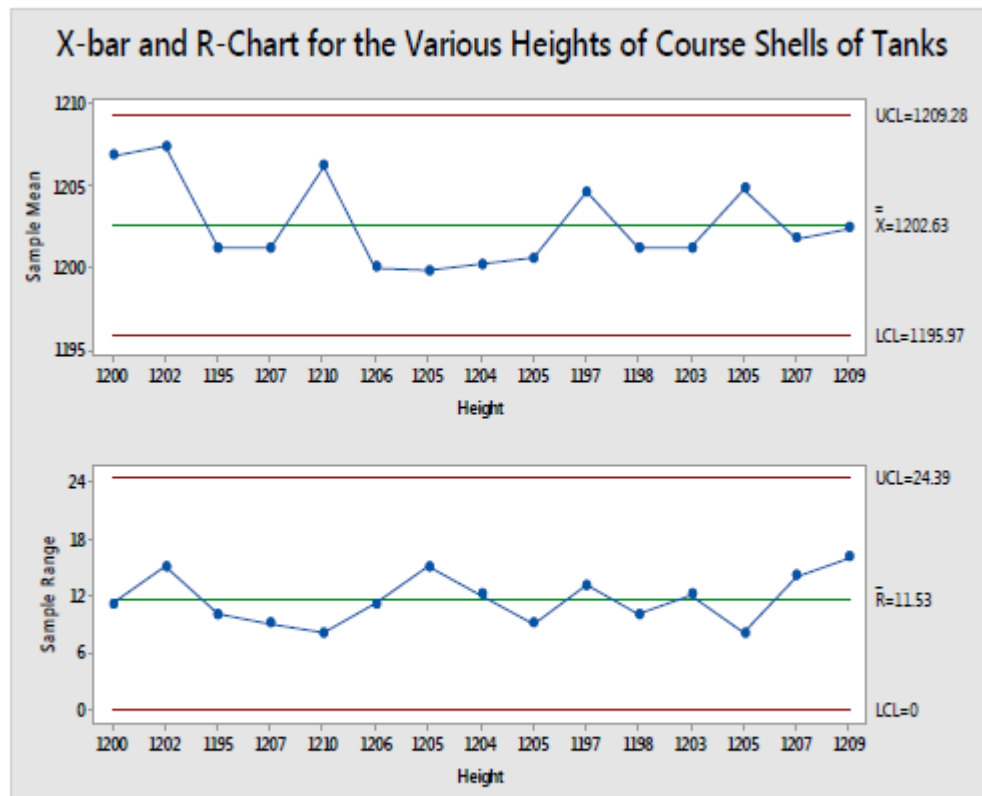


Fig. 5. X-bar and R-chart for the Various Height of the Course Shells

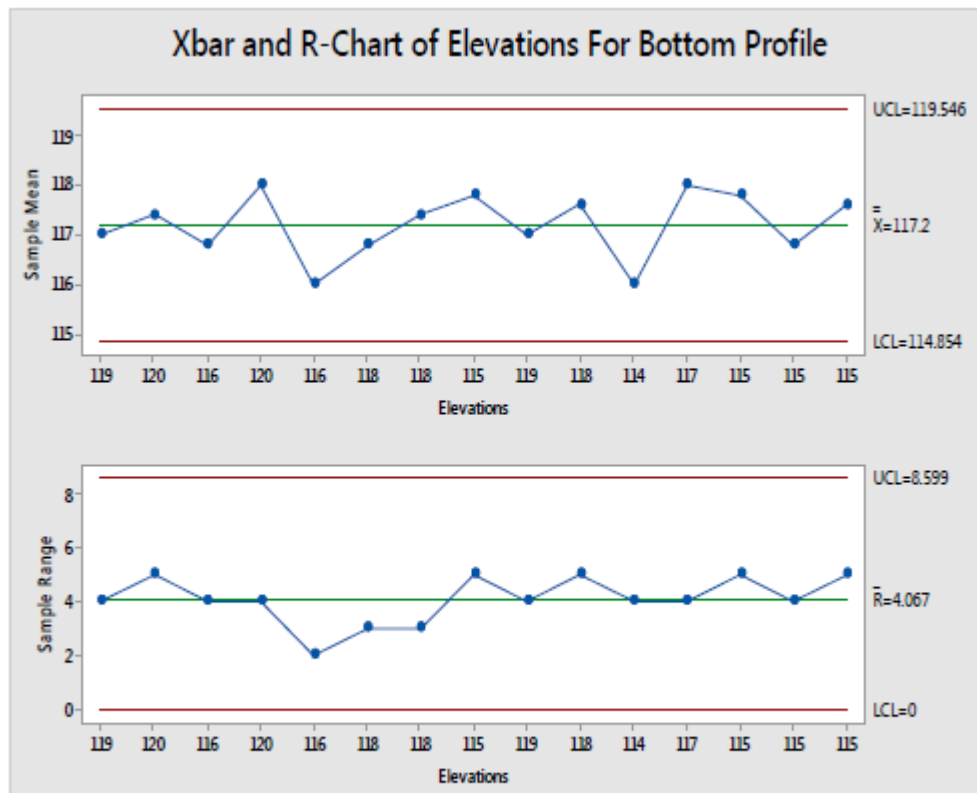


Fig. 6. X-bar and R-chart of Elevations for Bottom Profile

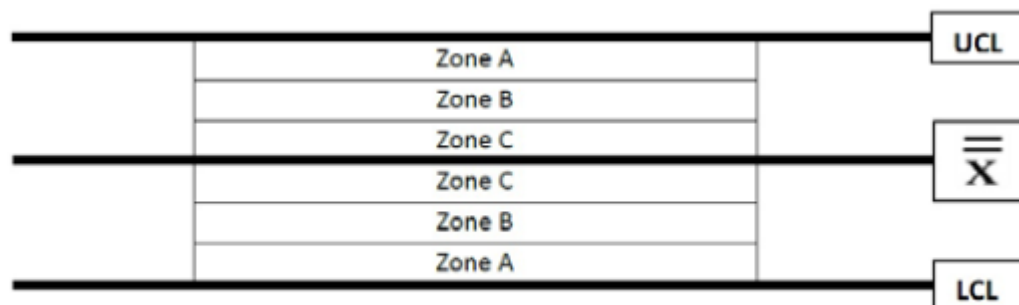


Fig. 7. Analysis of X-bar and R-control chart

5.2. DISCUSSION

To check if the calibration process is in control or not, “Run rules” were applied, first to the R-chart and then to the X-Bar chart by dividing the distance between centerline CL $(\bar{\bar{X}} \text{ or } \bar{\bar{R}})$ and Upper Control Limit UCL into three zones A(3), B(2) and C(1). The same procedure was applied for the distance between the centerline CL and Lower Control Limit LCL as shown in Figure 7.

1 4, 5 and 6 fulfilled all the conditions set out in Run rules and thereby confirmed that the process is stable (under control) with no assignable cause of variation.

Confirming that a process is stable is not enough; rather, it is expedient to check if calibration variables are within the pre-set limits/specifications. This was the reason for performing Process capability analysis on the obtained field data. The Process capability analysis for the measured Circumference, Height and Elevations were as shown in Figures 8, 9 and 10. Since all the Overall Capability indicators Pp, PPL, PPU, Ppk and Cpm as well as the Potential Capability (within) indicators CP, CPL, CPU and CPK were greater than one, and that implied that the process is capable of giving measurements (products) within the pre-set limits. Also, closer look at the process capability charts (Figures 8 – 10) revealed that the Normal distribution curves fell between Lower Specified Limit (LSL) and Upper Specified Limit (USL) which further confirmed the capability of the process.

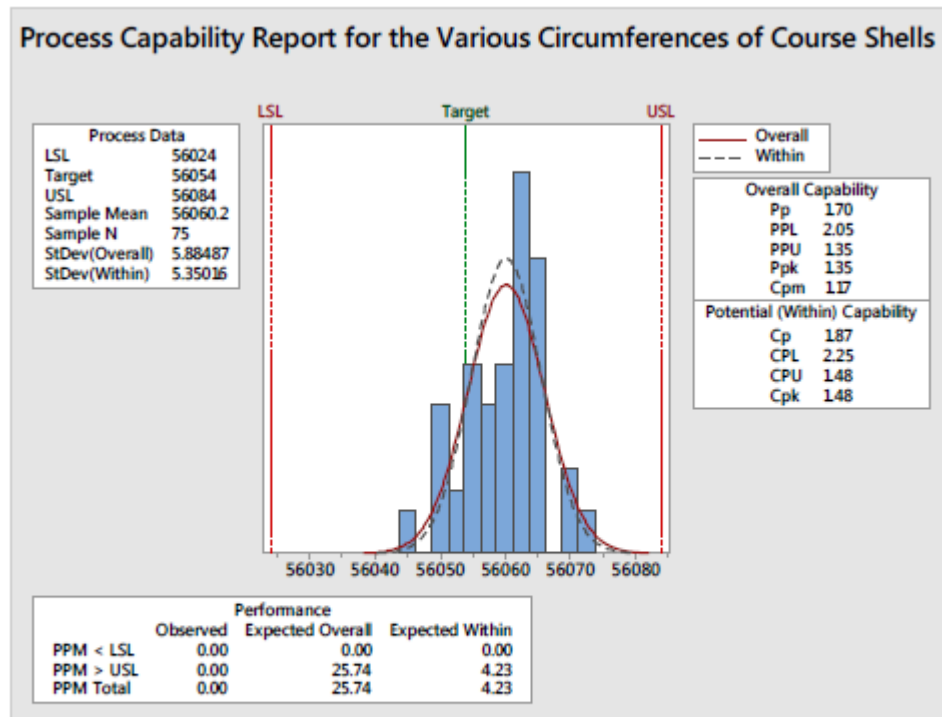


Fig. 8. Process capability analysis for the various Circumferences of Course Shells

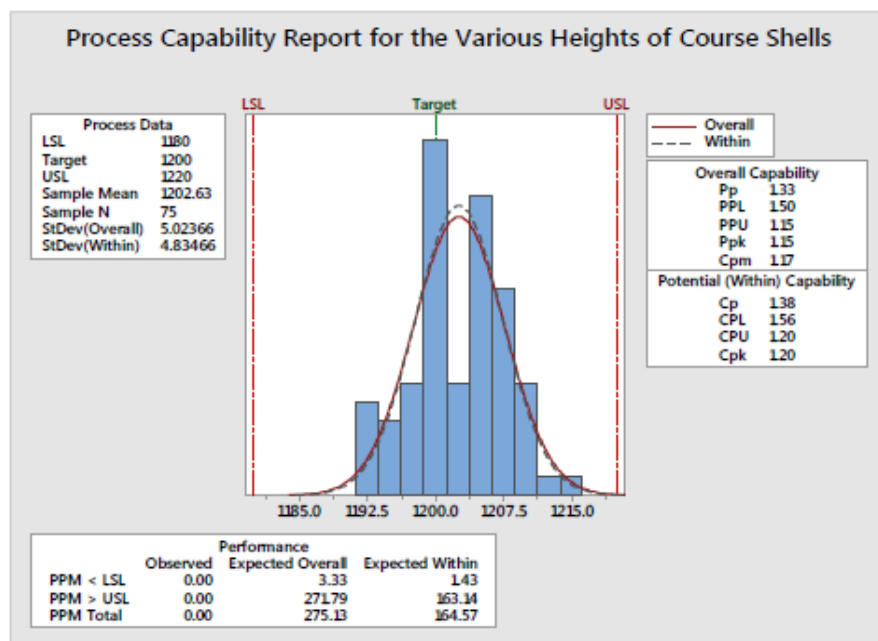


Fig. 9. Process capability analysis for the various Heights of the Course Shells

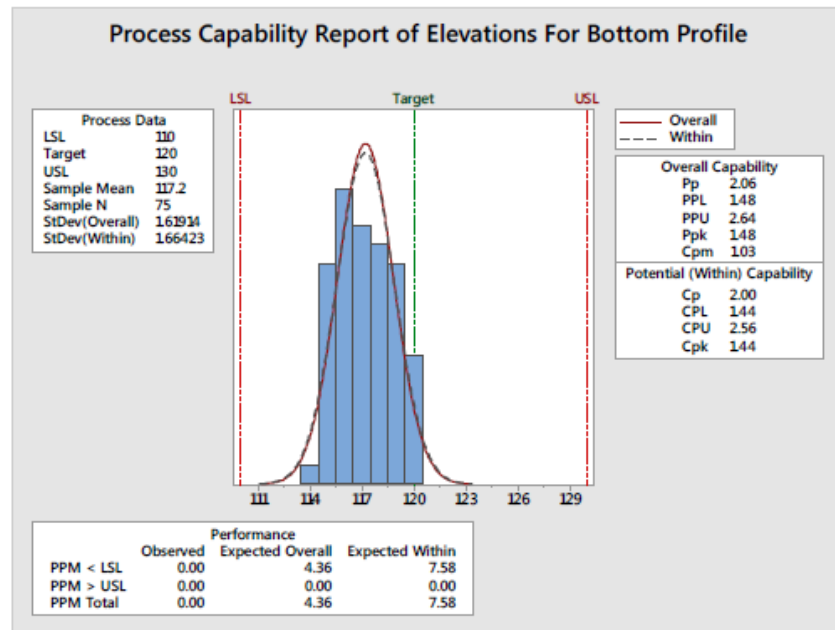


Fig. 10. Process capability analysis for the Elevations for the Bottom Profile

RESULTS AND DISCUSSION

The following are observational data related to the number of defects occurring in the "Shoulder" making process. The data is collected for 6 months

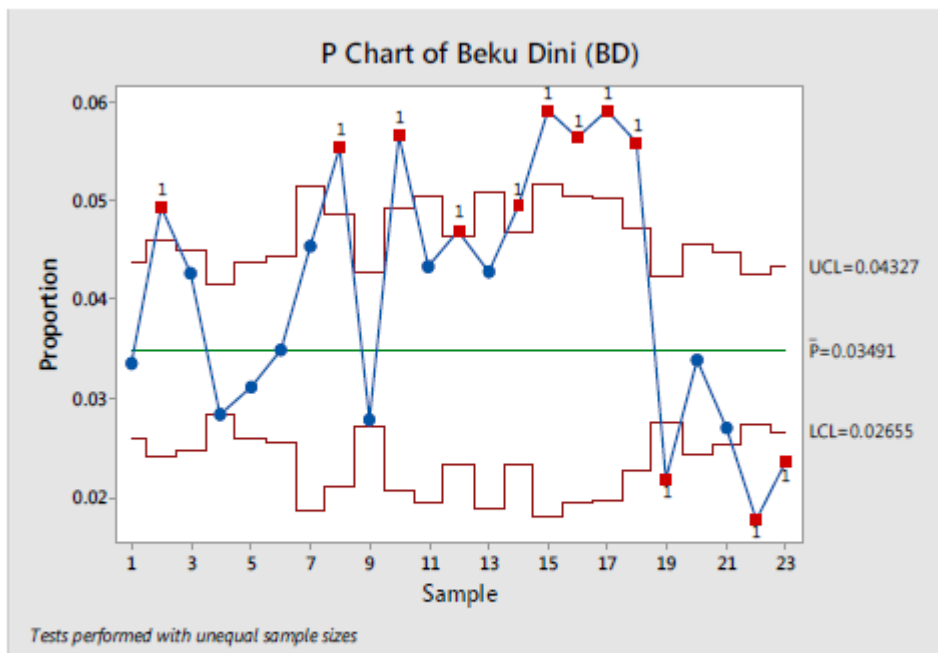
Product Defects Data

No	Sum	Defect					
		BD	IP	IT	D	RU	RC
1	3789	127	12	14	26	11	91
	2553	126	27	0	23	15	55
	2981	127	11	18	22	17	39
2	7078	201	20	46	33	6	118
	3819	119	9	10	5	0	121
	3446	120	25	25	24	2	43
	1125	51	0	3	2	4	11
3	1589	88	0	8	1	8	16
	5086	142	35	30	33	14	120
	1485	84	0	5	3	5	13
	1269	55	0	0	2	0	6

4	2298	108	2	3	27	5	29
	1194	51	13	7	12	11	11
	2184	108	4	8	29	6	41
	1067	63	5	3	5	0	10
5	1278	72	8	4	2	1	11
	1287	76	10	0	8	3	4
	2043	114	5	3	0	3	39
	5484	120	39	33	37	44	190
6	2694	91	39	17	9	18	50
	3225	87	10	7	21	3	107
	5343	95	42	38	24	15	119
	4338	102	33	14	18	16	100

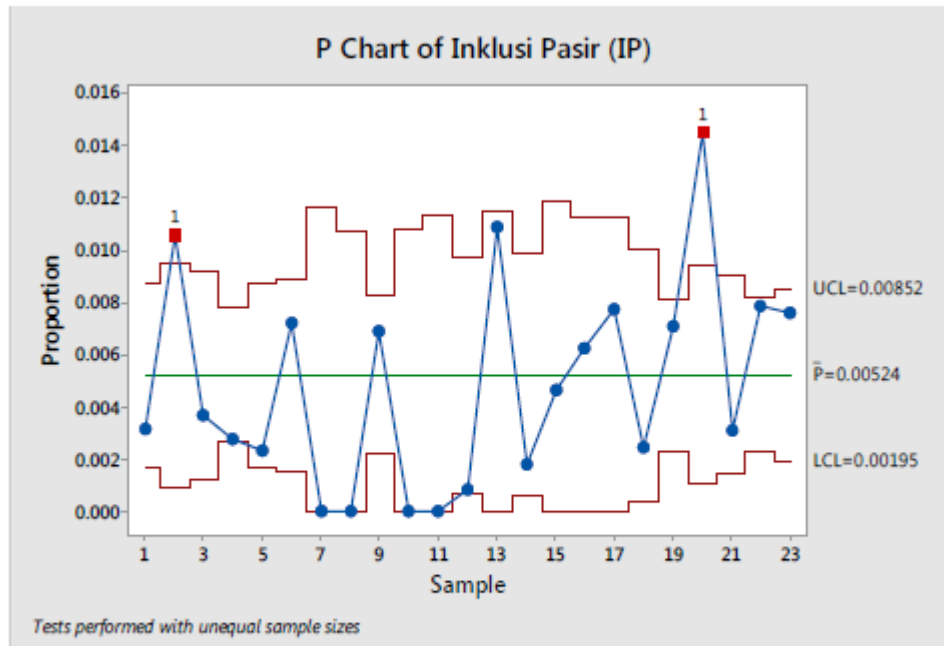
Early Frozen Analysis (BD)

Early frost is related to the conformity shown by the surface of the product, it appears that there is an unfilled portion of the liquid so that the "shoulder" wall is concave or convex as well as the presence of clumps on the product wall (Sendy 2017).



Control chart p with type of early frozen disability (BD)

Analysis of Inclusion Sand Mask (IP)



Control chart p on the inclusion of sand

BI's influence on IP

What is the relationship between the number of disabilities in the early freezing (BD) on the number of disability inclusion sand (IP)

Correlations BD And IP

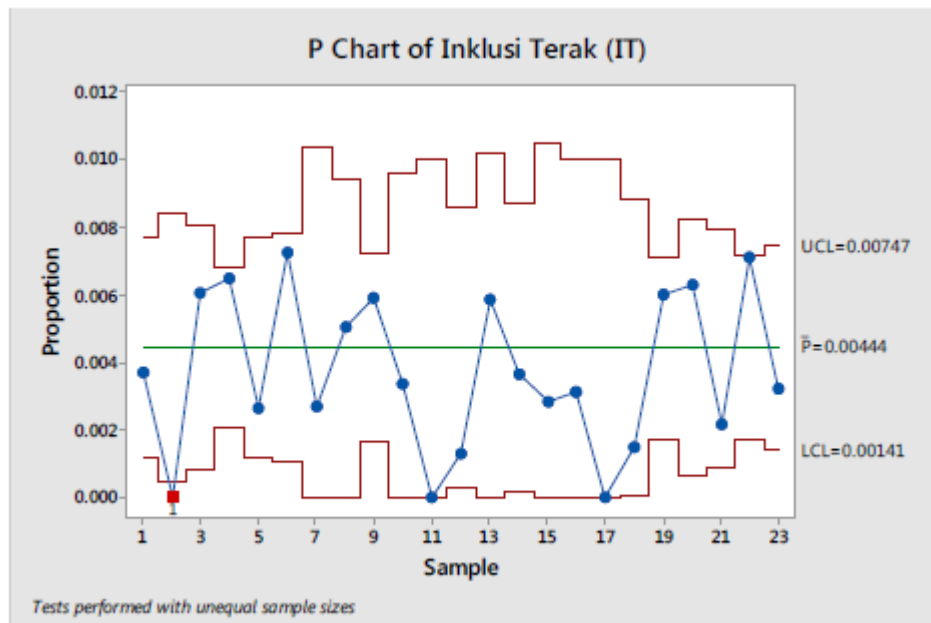
		BD	IP
BD	Pearson Correlation	1	.983 ^{**}
	Sig. (2-tailed)		.000
	N	24	24
IP	Pearson Correlation	.983 ^{**}	1
	Sig. (2-tailed)	.000	
	N	24	24

^{**}. Correlation is significant at the 0.01 level (2-tailed).

The data show that there is a significant relationship between the number of freeze frosts and the inclusion of Sand of 0.93, thus the influence of early frozen disability to the inclusion of Sand is equal to $(0.92)^2 = 81\%$, and another influence of 19%.

Inclusion Slag Analysis (TI)

The inclusion of slag is a type of conformance that is indicated by a hole on the surface of the product.



The effect of IP on IT

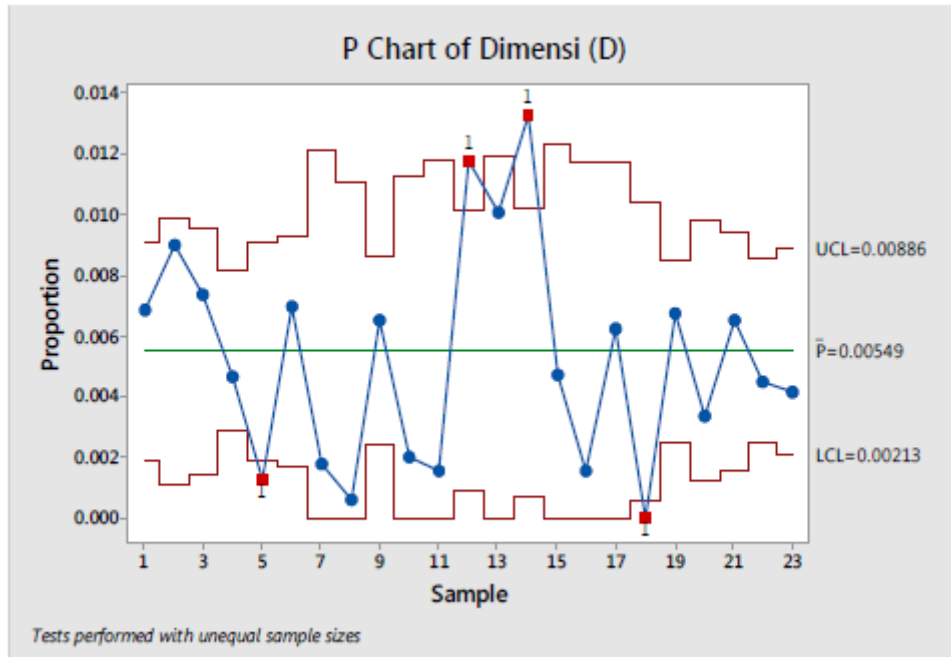
The magnitude of the disability relationship The sand inclusion with slag inclusion is 0.693 or to the strong correlation between the inclusion of sand inclusion with slag inclusion, of 0.987, while the magnitude of influence is 0.974% (0.987) 2. Thus it can be concluded that the disability inclusion of slag is caused by disability Sand inclusion of 97.4% while other factors of 2.6%.

Correlations

	IP	IT
IP Pearson Correlation	1	.987**
Sig. (2-tailed)		.000
N	24	24
IT Pearson Correlation	.987**	1
Sig. (2-tailed)	.000	
N	24	24

Dimensional Analysis (D)

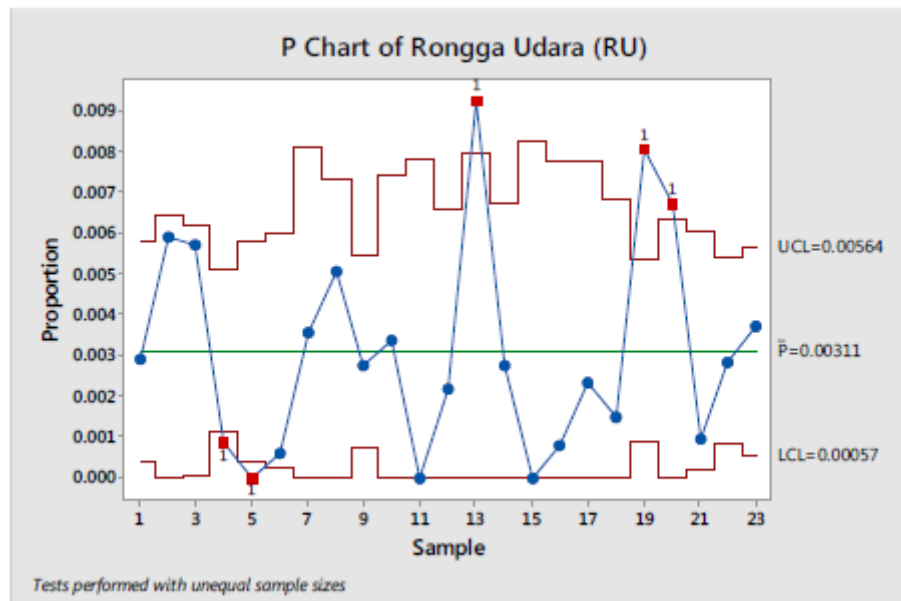
Dimensional defect is a disability related to the difference in the surface diameter of the product compared to the defined standard. Here is the control chart p , for dimensional defects



Based on the above data, it appears that the process is in an uncontrolled control. Some data that is number 5, 12, 14, 18 are out of control. Average percentage of rejection is 0.00549 with upper control limit of 0.00886 and lower control limit of 0.00213. Management can perform an in depth analysis of the process, due to the high variability of the product. Analysis can be done on the machine, labor, methods and also the environment that gives an opportunity out of control.

Air Cavity Disability Analysis (RU)

From the control chart p in Figure , it appears that the number of data is beyond the control limits of numbers 4, 5, 15, 19 and 20. The lower control limit is 0.00057 and the upper control limit is 0.000564, with the centerline of 0.0031. The control chart p that occurs on the air cavity shows an uncontrolled process which indicates the existence of data outside the control limit.



Influence of Dimensional Density (D) on Air Cavity (RU)

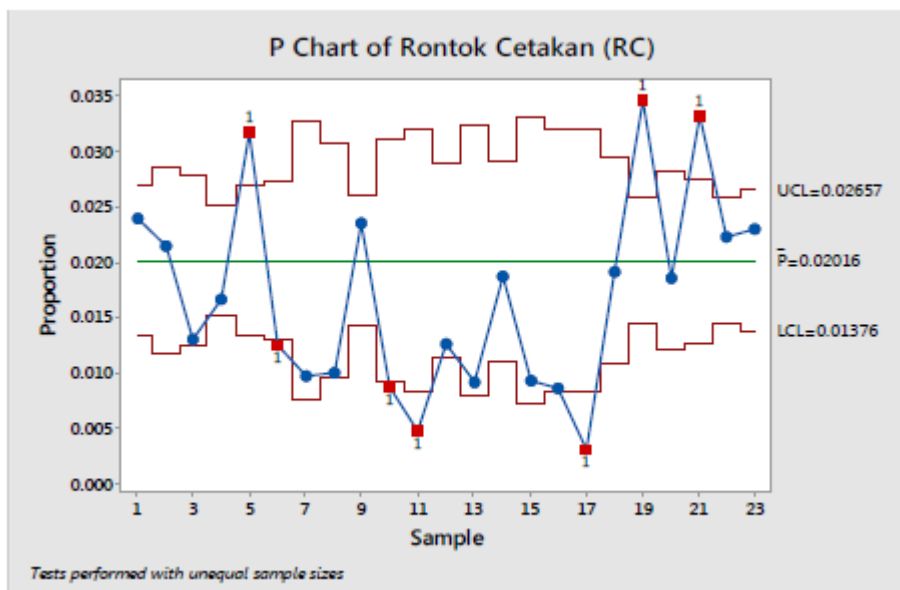
Correlations

		D	RU
D	Pearson Correlation	1	.981**
	Sig. (2-tailed)		.000
	N	24	24
RU	Pearson Correlation	.981**	1
	Sig. (2-tailed)	.000	
	N	24	24

**. Correlation is significant at the 0.01 level (2-tailed).

Analysis of Print Loss Disability (RC)

The print loss is a defect indicated by a lump on the surface of the product. Based on the control chart p, there are 7 data out of the control limit. There is a processed system that causes variability. The data in the control limits are in data numbers: 5, 6, 10, 11, 17, 19 and 22.

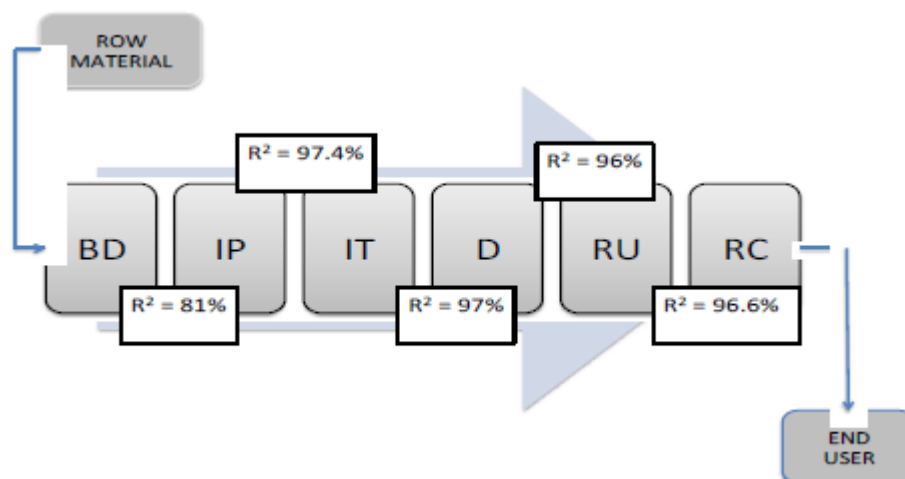


Effect of Air Cavity (RU) on Rupok Print (RC)

The magnitude of the effect of air cavity defects on the defects of cavities is 96.66%. Which is shown with correlation coefficient value of 0.983.

		RU	RC
RU	Pearson Correlation	1	.983**
	Sig. (2-tailed)		.000
	N	24	24
RC	Pearson Correlation	.983**	1

Influence of Inter-Process disability



CHAPTER-6

SUMMARY AND CONCLUSION

Only few of the quality managers use statistical quality control techniques or charts to monitor and improve the quality of their products and services. It could be possible that the quality control managers are not aware of the uses of statistical process control techniques or charts, as only 63% of the respondents indicated that they use statistical process control techniques and only 32% indicated that they use statistical process control charts. The need for the awareness of the uses of statistical quality control techniques and charts. In order to compete effectively with other companies, managers need to make decisions based on data. Just over 50% of managers use statistics in decision-making, this indicates the need for the awareness of the uses of statistics. It gives remedy for statisticians to make managers in the manufacturing industry and other industries aware of the uses of statistics in decision-making.

It was also found that the higher the respondents' statistical knowledge, the more frequently statistical quality control techniques are used. It may be concluded that if managers' statistical knowledge is improved, they would use statistical process control techniques more frequently and this would increase the number of managers making sound decisions in the assessment of the quality of their products. The quality of these managers' products would improve and their companies would be able to compete effectively in the global market.

A significant correlation existed between statistical knowledge and the use of statistics in decision-making. It does make sense that as the level of statistical knowledge increases so too does the use of statistics in decision-making. It is thus absolutely necessary for statisticians to help managers improve their level of statistical knowledge so that they use statistics more often when making decisions. This would result in managers making better decisions and this would improve the Indian economy.

Having successfully applied X-bar and R-control chart to the calibration of storage tanks manufactured unit, it has been observed that there is no assignable (special) cause of variation in the measured field data which could have resulted in sudden sharp change in the calibration chart. Since the calibration process for this group of tanks had been confirmed to be stable with high process capability index. It can be concluded that a calibration chart generated for one tank can be used for other tanks. Using one chart generated for one tank for the other ones will not only save cost but also reduce the time of generating tank calibration chart.

REFERENCES:

- [1] ISO 7507: Petroleum and Liquid Petroleum Products–Calibration of Vertical Cylindrical Tanks, ISO copyright office, Geneva, 2002.
- [2] Savaraman, S.: Vertical cylindrical storage tank calibration technologies and application, In- Proceedings of API Conference & Expo, Singapore, March 2012.
- [3] Agboola, O.O., Ikubanni, P. P., Ibikunle, R. A., Adediran, A.A., Ogunsemi B. T.: Generation of Calibration Charts for Horizontal Petroleum Storage Tanks Using Microsoft Excel, MAPANJournal of Metrology Society of India, In press.
- [4] Nosach, V., Belyave, B.: The calibration of large vertical cylindrical tank by a geometrical method, Journal of Measurement Techniques, Volume 45, pp 11, 2002.
- [5] Makushkin, S. G., Kuzmin, S. A., Kalashnik, G.G.: Tank Deformation and Accuracy in Measuring Oil Product Mass, Chemical and Petroleum Engineering, Volume 37, pp. 278, 2001.
- [6] Agboola, O. O., Kareem, B., Akinnuli, B. O.: Development of a diagnostic schedule for a defective LC-195V5 CNC milling machine using PERT, Leonardo Electronic Journal of Practices and Technologies, Volume 28, pp. 107-118, 2016.
- [7] Montgomery, D.C.: Introduction to Statistical Quality Control, John Wiley and Sons, Inc., 6th Edition, USA, 2009.
- [8] Steiner, S.H.: Grouped Data Exponentially weighted Moving Average Control Chart, Journal of the Royal Statistical Society, Series C, Volume 47, No. 2, pp. 203-261, 1998.
- [9] Ott, E.R., Schilling, E.G., Neubauer, D.V.: Process Quality Control Troubleshooting and Interpretation of Data, ASQ Quality Press, USA, 2005.
- [10]Page, E.S.: Cumulative Sum Chart, Technometrics, Volume 3, No. 1, pp. 1-9, 1961.
- [11]Woodall, W., Adam, B.: Quality Engineering, Volume 5, No. 4, pp. 559-570, 1993.
- [12]Ogedengbe, T. I., Apalowo R. K., Akinde A. B.: Application of Statistical Quality Control for Investigating Process Stability and Control in an Electric Wire Industry,

International Journal of Science and Technology, Volume 5, Number 3, pp. 81-87, 2016.

[13] Ali, R. M., Abdulkadir, G.: Statistical process control in machining: A case study for machine tool capability and process capability, Materials and Design, Volume 27, pp. 364–372, 2006.

[14] Jenn-Hwai, Y., Miin-Shen Y.: A control chart pattern recognition system using statistical correlation coefficient method, Computers & Industrial Engineering, Volume 48, pp. 205–221, 2005.

[15] Charles, J. C., Jeh-Nan, P.: Evaluating environmental performance using process control techniques, European Journal of Operational Research, Volume 139, pp. 68–83, 2002.

[16] Kapil, B., Amit P., Diptesh P.: Implementation of Statistical Quality Control (S.Q.C.) in Welded Stainless Steel Pipe Manufacturing Industry, International Journal of Research in Engineering and Technology, Volume 03, Issue 09, pp. 270-273, 2014.

[17] Tejaningrum. A. (2014) Inconsistency Quality Products (on Six Sigma Programs) Effect on Customer Loyalty: Case Study of Industry “Tahu”. Journal “Management Study” ISSN 2328-2185, January 2014. Vol 2 No 1. David Publishing USA.

[18] Tejaningrum.A.,Anton Azis.,Irlayanti (2015). Quality Culture for SMEs Model. Procceding Internatioanl Conference Actual Economic, Local Solution For Global Challenges. 2 sd 3 July 2015. Pattaya Thailand.

[19] Tejaningrum.,Mulyono.,Irlayanti (2015) . Measurement Quality Culture. Procceding Internatioan

[20] Tejaningrum . A. (2014a) Inconsistency Quality Products (on Six Sigma Programs) Effect on Customer Loyalty: Case Study of Industry “Tahu”. Journal “Management Study” ISSN 2328-2185, January 2014. Vol 2 No 1. David Publishing USA.

[21] Tejaningrum.A. (2014b) Analysis of Variance Quality Culture on a Difference Scale Production. International Conference Procceding of ICEHM. 30- 31 January, Pattaya Thailand.

- [22] Tejaningrum, A. (2012). Inkonsistensi Dimensi Kualitas Industri Kreatif UMKM Kota Cimahi dalam Mencapai Nilai Six Sigma. Proccedings from Seminar Nasioanl Kewirausahaan dan Industri Kreatif Bisnis II. SNKIB II Universitas Tarumanegara.
- [23] Tejaningrum. A. (2013). Effect of creativity and innovation production on performance of Organization (Case study of Industrial wood craft). Proceedings from 3rd International Conference on Management. Penang Malaysia
- [24] Oakland, J.S. (1989), Total Quality Management. London: Heinemann professional Publishing Ltd,
- [25] Pande, Neman and Cavanagh. In(2000). The Six Sigma Way. The McGraw-Hill
<http://www.sciedu.ca/journal/index.php/ijba/article/view/2801/1643>
https://www.ripublication.com/ijss17/ijssv12n2_19.pdf