American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-7, Issue-11, pp-290-303
www.ajer.org
Research Paper Open Access

Process Capability Study Of West African Glass Industry Plc, Port Harcourt, Nigeria

Douglas,P .O 1 And Lilly,T.M,2
〖1&2〗(Department of mechanical Engineering,Rivers State University portharcourt,Nigeria@Corresponding Author Douglas,p.o)
Corresponding Author: Douglas,P .O

***ABSTRACT** :The process capability study of Glass industry is investigated. This study is an invaluable way of analyzing and improving business process efficacy and efficiency. It examines the process capability index of the manufacturing process. The reason why process capability is a guide to both customers and suppliers was examined and how process capability study can help a business save huge amounts of money and increase profit margins. Data on raw materials and data on process products were systematically gather to ensure proper inspection capability procedures. Pearson Chi-square test was conducted on process data for normality distribution check. Process control charts were developed as guide to designers and manufacturers to what can be produced in terms of products tolerance. The control charts showed that the manufacturing process was not a perfect system as a few of the daily mean fell outside the control limits even though the product natural spread was seen to be in statistical control. The process yield information from this study showed that the process is competitive. Also appropriate recommendations are suggested for further research work in this area of study.*

Date Of Submission:15-11-2018 Date Of Acceptance: 29-11-2018

I. INTRODUCTION

Process capability is an important concept for industrial managers to understand. The challenge in today's competitive markets is to be on the leading edge of producing high quality products at minimum cost. The development and use of process capability indices have caused some controversy over the past few years, the indices have become one of the most popular statistical process control (SPC) tools in industry .[1]

For example, process capability indices are now an integrate part of most commercial SPC software used by manufacturing companies. In the manufacturing industry, it is of vital importance to know whether the process can produce parts that are within specifications or whether certain tolerance are achievable, and process capability indices are often used for these decision making tasks.[2]

Process capability information serves multiple purposes such as predicting the extent of variability that process will exhibit.[3]

Capability information when provided to designers provides important information in setting realistic specification limits. Also, it helps in choosing from among competing processes, that which is most appropriate for the tolerances to be met. Process capability index (Cp) defined as the Tolerance interval divided by six times the root of the mean squared deviation from target have been used as measure of quality level for shipped, products. There are manufacturers in the United States and Japan who required suppliers to produce items with a process capability index (Cp) of more than 1.00. for process capability index to be meaningful, the process itself must be stable. [4]

II. RELATED WORKS

Primitive forms of industrial society did not require specifications because the producers and the customers met face to face in the market place with the products physically present for inspection and evaluation by both parties. The industrial revolution of 1834 ushered in power-driven machinery that accomplished production at a faster rate and at a lower cost. This led to mass production of goods and also a high degree of automation in production. Since mechanized production replaced the work of craftsperson in many ways, the regular physical inspection and evaluation of product in the market place were no more present.[1]

Attainment of quality became less a matter of craftsmanship and more a matter of design, operations, construction etc. [2]

The need for specifications to be stated became paramount. The importance of tolerance and the control of manufacturing variation have received increased strive to improve productivity and in the quality of their products. There is a realization that it is no longer acceptable to arbitrarily select the tolerances in engineering drawings, as the effects of tolerance assignments are far reaching. Not only do the tolerance affects the ability to assemble the final products, but also the production costs, process, selection, tooling, set-up cost, required operator skills, inspection, scrap and network. The variation constrained or bounded by the tolerances also directly affect product performance and robustness of the design. And poorly performing products will eventually lose out in the market place.[3]

During the industrial revolution and subsequent years, variability was not investigated until it became manifest in the cost of scrap and network or loss of business through customer dissatisfaction.[4].

Designers had to deal with this by specifying tolerances, which are allowable variation from the normal values. In 1924, Schewart, of Bell Telephone laboratory introduced statistical control charts.[5]).

This was believed to be the beginning of statistical quality control. He originated the technique of plotting statistical dat5a on special charts in such a manner as to contribute to control of quality. It should be emphasized that conceptually tolerance limits are different from control limits developed for control charts. The tolerance limits are designed requirements while the control limit depends on how the process actually operates [6].

Process can produce acceptable product.[7]. Process capability studies indicate if a process is capable of producing virtually all-conforming product.

Nelson (1967) stated that the chief aim of quality control in maintaining statistical control on a manufacturing process is to keep production within specifications. For manufactured items that will be used as components in an assembly to ensure that assemblies manufactured from the components will perform satisfactorily. [8]

He stated that proper choice of components specifications is essential to successful mass production of assemblies that perform within specifications. For manufactured items that will be used as components in an assembly to ensure that assemblies manufactured from the components will perform satisfactorily. He stated that proper choice of components specifications is essential to successful mass production of assemblies that perform within specifications. Before the introduction of process capability indices in early 1080's, the common method for estimating the characteristics of a production process was to estimate and examine the tolerance limits of the process (Hald, 1952) Bhote (1988) reports that prior to the widespread use of statistical quality control techniques (prior to 1988), the normal quality of US manufacturing process was approximately Cp – 0.67. This means that 33/2 percent tail areas of the normal curve falls outside specification limits. As of 1988, only 30% of US process is at or below this level of quality (See Bhote, 1988, page 51). Ideally, of course, we would like the index to be greater than 1, that is, we would like to achieve a process capability so that is, we would like to achieve a process capability so that no item falls outside specification limits. Interestingly in the early 1980s the Japanese manufacturing industry adopted as their standard Cp = 1.33. Minimum values are recommended for process capability study.[9]

III. MATERIALS AND METHODS

3.1Theory of Model Development

The process chapter attempted to introduce and present a brief literature survey of process capability study. In this chapter an attempt is made to look at he process capability of the glass production process using West African Guinness Malt glass container for evaluation purpose. There are different types of glass containers that can be produced in a glass factory. Fanta glass container, Cocoa-cola glass container, malt, schnapps, guilder, star, pharmaceutical drink containers, etc. are some example of glass containers produced in this glass factory. Every product has its own design and customer's requirements.

Process capability study is a segment of statistical quality control that allows one to quantify how well a process can produce acceptable product. [1]

As a result, a manager or an engineer can prioritize needed process improvement and identify those processes that do not need immediate improvement. Process capability indicates if a process is capable of producing virtually all-conforming products or not. If the process is stable and capable, then statistical effort can be reduced or eliminated entirely. This not only yields great cost savings but alos eliminates scraps, rework and increase customers' satisfaction. After a process study has been performed, a process will be classified as either capable or incapable. When the process is not capable of producing virtually all conforming products, the process is said to be incapable and acceptable sampling procedures for 100% inspection) must remain part of the process.

Process may also start out as capable but changes over time to have more variability. In addition, the process may also shift placing the process too close to one of the specification limits. Both increases in process capability and shifting of the mean may result in once capable process becoming incapable.

3.2 Process Capability Study Steps

The following basis steps to conduct a high quality process capability study are as follows:

1. **Select Critical Parameters**: This is selecting a candidate for the study. Critical parameters need to be selected before the study begins. Critical parameters may be established from drawings, contracts, inspection instructions, work instructions, etc. critical parameters are usually correlated to product fit and/or function.
2. **Collect Data**: A data collection system needs to be established to assure that the appropriate data is collected. It is preferable to collect at least 60 data values for each critical parameter. If this is not possible, corrections can be made to adjust for the error that is introduced when less than 60 data values are collected significant digits for each data should be the number of significant digits required per the specification limits plus one extra significant digit to assure tat process stability can be evaluated.

3.**Establish control over the Process**: Evaluate the measurement system. A distinction between product and process should be made at this point. The product is the end result from the process. The product may be a physical item (Example fabricated part) or a service (example: typing a report). One may control the process by measuring and controlling parameters of the product directly or measuring and controlling the inputs to the process (once correlation between the process inputs and product critical parameters have been established). It is ultimately desirable to establish control over the process by controlling the process inputs. On the other hand, process capability indices are always performed using the critical parameters of the product. Calculation of predictable process capability indices is dependent on the statistical control of the process. If the process is not in statistical control, then the results of the study are subject to fluctuate unpredictably. The statistical control of the process can be studied using control charts (usually X-bar charts).

4.**Analyze Process Data**: Prepare a control plan. To calculate the process capability indices, estimates of the process average and dispersion (standard deviation) must be obtained from the process data. In addition, the formulas for process capability indices assume that the process data came from a normal statistical distribution. It is important that one prove that the data is normally distributed prior to reporting the process capability indices because errors in misjudgment can lead to the same undesirable effects was listed in Step 1. Methods for handling non-normal data and formulas for several process capability indices will be addressed in separate sections.

5. **Analyze sources of Variation**: Select a method for the analysis, gather and analyze the data. Study of the component sources of variation and their magnitudes may range from simple statistical tests to complex experimental designs carried out over a long period of time. If possible, tests should be kept simple. Analyzing sources of variation involves determining what process factors affect the natural process spread (process variation) and the process centering. With this knowledge, it may be possible to improve the process capability. Analyzing sources of variation always involve careful planning and data collection.

6.**Establish Process Monitoring System**: Tract down and remove special causes and establish a plan for continuous process improvement. Once the process capability indices indicate a capable process, a routine process control technique should be employed to assure that the process remains stable. This may be done by a variety of methods such as establishing a statistical process (SPC) programme.

3.3 Analyse Sources of Variation

Study of the component sources of variation and their magnitude may range from simple statistical test to complex experimental designs carried out over a long period of time. If possible, tests should be kept simple. Analysing sources of variation involves determining what process factor affects the natural spread (process variation) and the process. With this knowledge, it may be possible to improve the process capability. Analyzing sources of variation always involves careful planning and data collections.

3.4Process Capability Indices

Calculating the Process Mean ($\overline{X}$)

Mean = $\overline{X} = \dfrac{\sum X_i}{n}$ (3.1)

where, X_i = Data value

n = Sample size

3.5 Calculation of the Process Spread (Standard Deviation, S)

$$S = \sqrt{\frac{\sum (X_i - Mean)}{(n-1)}} = \sqrt{\frac{\sum (X_i - Mean)}{(n-1)}} \quad (3.2)$$

To obtain an accurate estimate of the process spread (standard deviation) at least 60 data point is needed. If less than 60 data points are available, use the following formulae with the error correction factor.

$$S_{corrected} = \frac{S}{C_4} \quad (3.3)$$

where C is a constant.

Table 3.1 Standard Deviation Correction Factor

N	C_4
15	0.923
16	0.9835
17	0.9845
18	0.9854
19	0.9862
20	0.9869
21	0.9876
22	0.9882
23	0.9887
24	0.9892
25	0.9896
30	0.9914
35	0.9927
40	0.9936
45	0.9943
50	0.9949
55	0.9954

3.6 Calculating Process Capability Indices (Cp)

Table 3.2 Commonly Accepted Process Capability Indices

Index	**Description**
$C_p = \dfrac{USL - LSL}{6 \times \delta}$	Estimate what the process should be capable of producing if the process could be centred. Assumes process output is approximately normally distributed
$C_{pLower} = \dfrac{N - LSL}{3 \times \delta}$	Estimate capability for specifications that consist of a lower limit only (for example, strength) Assumes process output is approximately normally distributed.
$C_{pUpper} = \dfrac{USL - N}{3 \times \delta}$	Estimates process capability for specifications that consist of an upper limit only (for example concentration). Assumes process output is approximately normally distributed.
$C_{pk} = Min\left[\dfrac{USL - N}{3 \times \delta}, \dfrac{N - LSL}{3 \times \delta}\right]$	Estimates what the process is capable of producing if the process target is centred between the specification limits. If the process mean is not centered, Cp overestimates process capability Cpk. If the process mean falls outside of the specification limit. Assumes process output is approximately normally distributed.
$C_{pm} = \dfrac{C}{\sqrt{1 + \left(\dfrac{N - T}{\delta}\right)}}$	Estimate process capability around a target, T/Cpm is always greater than zero. Assumes process output is approximately normally distributed. Cpm is also known as the Taguchi capability index.
$C_{plan} = \dfrac{C_{pk}}{\sqrt{1 + \left(\dfrac{N - T}{\delta}\right)}}$	Estimate process capability around a target T, and accounts for an off-center process mean. Assumes process output is approximately normally distributed.

Source: Wikipedia, the Free Encyclopedia
σ is estimated using the sample standard deviation.
There are many process capability indices available. Presented here are several of the most common indices.

3.6.1 Process Capability Indices (Cp)

This is a process capability index that indicates that the process potential performance by relating the natural process spread to the specification (tolerance spread. It is often used during the product design phase and Pilot Production phase.

$$Cp = \frac{Specification\ Range}{6\ \delta} = \frac{USL - LSL}{6\ \delta} \qquad (3.4)$$

where USL is the Upper Specification Limit, and
LSL is the Lower Specification Limit
S is the standard deviation

3.6.2 C_{pk} (2-Sided Specification Limits)

This is a process capability index that indicates the process actual performance by accounting for a shift in the mean of the process forward either the upper or lower specification limit. It is often used during the pilot production phase and during routine production phase.

$$C_{pk} = \text{Minimum}\left[\frac{USL - Mean}{3\delta}; \frac{Mean - LSL}{3\delta}\right] \qquad (3.5)$$

C_{pku}=C_{pk} (Upper specification limit)
C_{pkl}=C_{pk} (lower specification limit)

3.6.3 C_{pk} (1-Sided Specification Limits)

Cpk can be calculated even if only one specification limit exists ore if a minimum/maximum is specified.

(a)$C_{pk(max)}$: C_{pk} for upper specification limit or maximum

$$C_{pk(max)}: = \frac{(USL - Mean)}{3\delta} \qquad (3.6)$$

(b)$C_{pk(min)}$: C_{pk} for lower specification limit or minimum

$$C_{pk(min)}: = \frac{(USL - Mean)}{3\delta} \qquad (3.7)$$

3.6.4 Capacity Index for Attributes Data

Ford Motor Company established a capability index for attributes (go/no-go) data.
(a)No failure to meet specifications

$$\text{Capability \%} = 100\,(0.5)^{\frac{1}{n-1}} \qquad (3.8)$$

(b)With failure to meet specifications

$$\text{Capability \%} = 100\left[1 - \frac{F + 0.7}{n}\right] \qquad (3.9)$$

where F = No. of failures

Table 3.3 Cp Value Corresponding to Capability %

Equivalent Cp	Capability %
0.50	86.64
0.62	93.50
0.68	96.00
0.75	97.50
0.81	98.50
0.86	99.00
0.91	99.35
1.00	99.73
1.33	99.94

Source: Don Winton (1999

3.6.5 Capacity Index for Use with Target Values C_{pm}

Cpm is used when a target value other than the center specification spread has been designated as desirable.

$$Cpm = \frac{C_p}{\dfrac{1+(\overline{X}-T)}{S^2}} \qquad (3.10)$$

where T is the process target value other than the unity of the specification.

3.6.6 Capability Index for "Smaller is Better" Quality Characteristics, Cr

Cr express Cp in a ratio format and is often used as a "Smaller is Better index.

$$Cr = \frac{100}{C_p} \qquad (3.11)$$

For the purpose of this project the process capability Indices, Cp and Cpk will be considered and evaluated because other indices are used for special situations, as indicated.

3.6.7 Process capability Analysis from Control Charts

Control charts are used to monitor the process after the initial process capability evaluation. The control chart may be used to obtain an estimated of the standard deviation and the process mean for use in the process capability formulas. Use the following formulas to obtain the mean and standard estimated with the appropriate error correction factors from table below:

Mean = $\overline{X}$

$$\sigma = \frac{\overline{R}}{d_2}$$

$$\sigma = \frac{\overline{S}}{C_4} \qquad (3.12)$$

In this case, the grand mean ($\overline{X}$) is used as an estimate for the process mean ($\overline{X}$).

Table 3.4 Standard Deviation Correction Factors

N Subgroup Sample size	D2	C4
2	1.128	0.7979
3	1.693	0.8862
4	2.059	0.9213
5	2.326	0.9400
6	2.534	0.9515
7	2.704	0.9594
8	2.847	0.9650
9	2.970	0.9693
10	3.028	0.9727
11	3.173	0.9754
12	3.258	0.9776
13	3.336	0.9794
14	3.407	0.9810
15	3.472	0.9823

Source: Don Winton (1999

3.7 Process Capability Related to Percent Non-Conforming

Process capability indices indicate the inherent capability of a process but what does this mean with respect to yield and percent non-conforming that may be expected from the process.

Many process capability indices (Cp, Cpk) may be expressed in terms of percent non-conforming by using the standard normal tables. Present here is the procedure to convert Cp and Cpk into a percent non-conforming value. The procedures presented here assume that the normal tables used, define the area less than or equal to the Z-score. Other tables need to be interpreted appropriately.

3.8 Converting Cp to Percent Non-conforming

Step 1: Calculate the Z-score

$$\text{Z-score} = 3C_p \qquad (3.13)$$

The Z-score is the Z-percentage point from the standard normal distribution tables. In fact, Cp and Cpk assumes that the process data follows a normal distribution.

Step 2: Use the Z-score to find the Z-score curve area value in the standard normal table. Since the Z-score is the Z percentage point, the area under the normal distribution curve can be looked up directly in the normal tables.
Step 3: Convert the Z-score curve area to process percent non-conforming and process yield.

Process percent nonconforming = 10 – Z score curve already (2)
(100) (3.14)

The process percent non conforming is the long term percent non-conforming that can be expected from the process if it is allowed to operate at the current capability.
The long term process yield is:
Process yield – 100 – Process percent Non-conforming
Process yield indicates the long term process yield that can be expected from the process if it is allowed to operate at the current capability.

3.9Converting Percent Non-Conforming to C_p.

Step 1: Calculate 1.0 = $\frac{\text{Percent Nonconforming}}{(100)\ (2)}$ (3.15)

This is the Z-score curve area that will be used to obtain the Z-score percentage point from the normal tables.
Step 2: Using the standard normal tables as the quantity obtained in Step 1, obtain the Z-score.
Step 3: Convert the Z-score to the equivalent Cp.

$$Cp = \frac{Z - score}{3} \quad (3.16)$$

To obtain the percent non-conforming from C_{pk}, the percentages from both tails (C_{pku} and C_{pkl}) needs to be calculated and the results added.

3.10 Process Capability Index Standards
The current process capability index standards for Cp and Cpk are:
Cp > 1.33
Cpk > 1.33

Tis value is selected to be 1.33 for a number of reasons. Processes are seldom truly static and this value allows for small process shifts. For example, if Cpk changes from a value of 1.0 to 00.67 (shift a one standard deviation), the process experiences increase from 0.27% to 4.55% non-conforming. In addition, serial processes usually contribute an additive effect for non-conformers and high process capability indices assure an acceptable end-of line Cpk.

3.11Inspection Capability Theory

Inspection capability is a method for evaluating and quantifying an existing inspection system. Inspection capability study determines if an inspection method or piece of equipment produces acceptable, marginal or unacceptable result. If unacceptable, then the equipment has to be calibrated or buy a new caliper.
Inspection capability studies are to:
Evaluate non-measuring equipment or inspection methods.
Compare one or more of the same type of measuring equipment.
Compare measuring equipment before and after repaid or adjustment
Compare inspection techniques between suppliers and between the supplier's final inspection and the customer's receiving.
Inspection capability studies measure and quantify the repeatability and reproducibility of the measurement and inspection method.
Inspection capability studies measure and quantify the repeatability and reproducibility of the measurement and inspection method.

3.12Repeatability

Repeatability is the variation resulting from the inability of the measuring instrument to obtain the same result repeatedly due to the numerous little things that make up the measuring system (friction from spring, etc.) and the in ability of the checker to operate and read the instrument exactly the same way every time. Repeatability may be determined by measuring the same part several times. For attribute date, repeatability is defined to be the variation in classifying part as conforming or non-conforming when one person inspects the same part several times using the same inspection method, criteria or equipment.

3.13 Reproducibility

Reproducibility is the variation among the people doing the measurement not or inspection using the same methods or equipment. It is more properly called lack of reproducibility. The variation among identifiable measuring instruments used by the same person is another source of lack of reproducibility.
Reproducibility may be determined by having another person measure the same part with the same instrument

3.14Inspection Capability

Repeatability and reproductively are qualified and combined to determine the inspection capability for variable data, the percentages of the total tolerance consumed by the capability (PTCC) is calculated. For attribute data the capability cannot be expressed as a percentage of a tolerance. The emphasis for attribute data is on how effective a person is at detecting conforming or non-conforming parts and how biased a person is toward rejecting conforming parts or accepting non-conforming parts.
The end result of the study is to determine if the measurement and inspection method is acceptable, marginal or unacceptable according to given criteria.

3.15 Inspection Capability Study for Variable Data

When a part is measured, each reading obtained on a single piece consists of the true, a constant error and the repeatability error.
Reading – True value constant error/repeatability error
The true value of a part does not change when repeated measurement are made on it. The deviation from the true value occurs because the measuring instrument is off calibration. It is the same for all readings and is thus called constant error.

3.16 Definition of Inspection Capability Evaluation

1.Repeatability factors for inspection capability studies involve data
2.Computing the upper control limit for

UCLR =UCLB = D4 $\overline{R}$ (3.17)

where $\overline{R}$ = Centre line for R chart (mean)
3.Repeatability evaluation standard deviation of repeatability (SDR)

R =Average range $1/d_2$ = factor

SDR = $1/d_2\ \overline{R}$ (3.18)

Repeatability = $6 \times$ SDR (3.19)
PTCC =Total Tolerance Consumed by capability
PTCR =(6 × SDR/ Total tolerance) × 100% (3.20)
4.Repeatability evolution (Appraisers)
RM=Difference between the average

RM= $\overline{X} - \overline{X}_o$ (3.21)

$\overline{X}$ =Large average

$\overline{X}_o$ =Smaller average
SDM Standard deviation of reproducibility
D=Factor
Reproducibility = 6 × SDM (3.22)
PTCM =Percentage tolerance consumed by Reproducibility
PTCM =6 × SDM/ Total tolerance × 100% (3.23)
Inspection capability evaluation

SDC = $\sqrt{(SDC^2) + (SDM)^2}$ (3.24)

3.17Control Chart

A process can e maintained in the state through the use of quality control chart. The centerline of the chart is the average quality characteristics being measured; the upper control limit represents the maximum acceptable random variation when a state of control exists. Generally speaking, the upper control limits are set at three standard deviations from the mean. When the measurement falls within the control limits, the process is in control. If the measurement falls outside the control limits, the process is stopped and search is made for an assignable cause. Through this procedure, the process is maintained in a state of statistical control and there is only natural variation in the process's output. Just as in the case of acceptance sampling quality can be measured for control charts by attributes or by variables.

3.18 Control Chart for Variables

Variable control charts are extremely used in process additional knowledge about the process. It gives information about intending situation and gives enough time to act. Its drawback is that it is more expensive to collect data because the data are more. It takes longer time and at higher cost. Its advantages are that it requires smaller sizes to develop a control chart.

The two measures of interest are:

General tendency

Dispersion

In application, it is generally necessary that dispersion is in control before examining the central tendency (X and R). To ensure R and X are in control you must set a standard upper specification and lower specification limits. If a process standard deviations increases with no change in the central tendency, the fraction of product failing out of specification limits may be unacceptable. Using X-bar chart initially might not allow a problem to be detected. The other probability occur when there is a shift in the process mean, with no shift in the standard deviation although this change will not be detected on R-chart, it will be detected in the X-chart.

3.18.1 X-Chart

$$\bar{\bar{X}} = \frac{\sum \bar{X}_1}{n} \qquad (3.25)$$

n = Sample

Upper Control Limits

$$UCL_{\bar{X}} = \bar{\bar{X}} + \frac{3R/d^2}{\sqrt{n}} = \bar{\bar{X}} + A_2\bar{R} \qquad (3.26)$$

CL = Mean value of quality characteristics

Lower Control Limit

$$LCL_{\bar{X}} = \bar{\bar{X}} - \frac{3R/d_2}{\sqrt{n}} = \bar{\bar{X}} - A_2\bar{R} \qquad (3.27)$$

3.18.2 R-Chart

Upper Control Limits

$$UCL_{\bar{R}} = \bar{R} + 3dR = \bar{R} + 3d_3\frac{(R)}{d_2} = \bar{R}D_4 \qquad (3.28)$$

$UCL_{\bar{R}}$ = $\bar{R}$ average range

Lower Control Limit

$$LCL_{\bar{R}} = \bar{R} - 3dR = \bar{R} - 3d_3\frac{(R)}{d_2} = \bar{R}D_3 \qquad (3.29)$$

3.19 Process Capability Index (C_{pk}) and Trended Processes

As stated earlier, this is a process capability index that indicates the process actual performance by accounting for a shift in the mean of the process tow and wither the upper or lower specification limit (Suozzi, 1990). This is equally the case as many processes show certain intrinsic trend pattern. As long as this is within a certain range, it is considered acceptable. A common example is the tool wear process which exhibits a trend in the process mean level because of the physical nature (M. Xie and T. N. Goh, 2000). Because of the nature of the tool wear the usually appearance of such process always indicates the existence in auto correlation. Hence, a general approach is first to fit a time series model to the tools wear data set and then control charts can be applied to the residue.

A number of different time series models have been used in statistical process control (SPC) with different assumptions. Typical time series model employed are the autoregressive integrated moving average

(ARIMA) model, exponential weighted moving average (WEMA), double exponential smoothing technique (DES) etc. for the purpose of this project, only DEC technique will be considered.

3.20Double Exponential Smoothing (DES) Model

For simplicity, a tool wear process can be appropriately described by:

Y1 = utn + uti + et (3.30)

Where, et is a system of an independently and identically distributed random variable. When the values of the parameters U0 and U1 are shown by changing over time. DES is a desirable technique for forecasting the mean of the process. We obtain updated values of the smoothed statistics X1 and (X_1^2) using the following equations:

Xt = λyt + (1 - λ)Xt – 1 (3.31)

X_t^2 = λyt + (1 - λ) X_t^2 – 1 (3.32)

Where both of these equations employ the same smoothing constant λ which is defined as O → λ < 1, and Yt represent the observed value as Xt and X_t^2 are values of the smoothed statistics computed in time period t – l.

A forecast for the mean of the process at time for the future value Yt + 1 can be derived as:

$$Yt + l(i) = \left(2 + \frac{\lambda}{1-\lambda}\right)xt - \left(1 + \frac{\lambda}{1-\lambda}\right)xt^{(2)} \qquad (3.33)$$

And the one step chart prediction error using (DES) forecast is

Et = Yt – yt (t – l) (3.34)

If the underlying (DES) model is appropriate, control charts can be applied to these one step ahead prediction errors because they are independently and identically distributed. The control limits and center line of (DES) control chart can be derived as follows:

UCLt + 1(t) = Yt + 1(t) + 3δ (3.35)

UCLt – 1(t) = Yt – 1(t) – 3δ (3.35)

(DES) technique is used to eliminate the trend component of the tool wear process and the actual monitoring is applied to the process residue using the 3-sigma control chart.

IV. RESULTS AND DISCUSSION

This research work used only two product variables as process data. They are locking ring/tread and capacity dimensions of the product.

From Figure 4.2, the X-chart control chart for tread/locking ring shows that four daily mean for 1, 15, 17 and 29 day falls outside the control limits. This is understood against the background that the manufacturing process is not a perfect system. It can be said to be [he period as shown in Figure 4.4 shows that the range fur day 13, 27, 28 falls outside the control limit. This is also explained by the imperfection of the manufacturing process.

Also, for the 2nd month of tread/locking ring as shown in figure 4.3, the X-bar control charts had a mean on day 33, 35, 45 and 50 falling outside the control limits. This is also explained by the imperfection of the system. However, the natural product spread for the period shows that only 2 ranges fall outside* the control limits as shown in Figure 4.5.

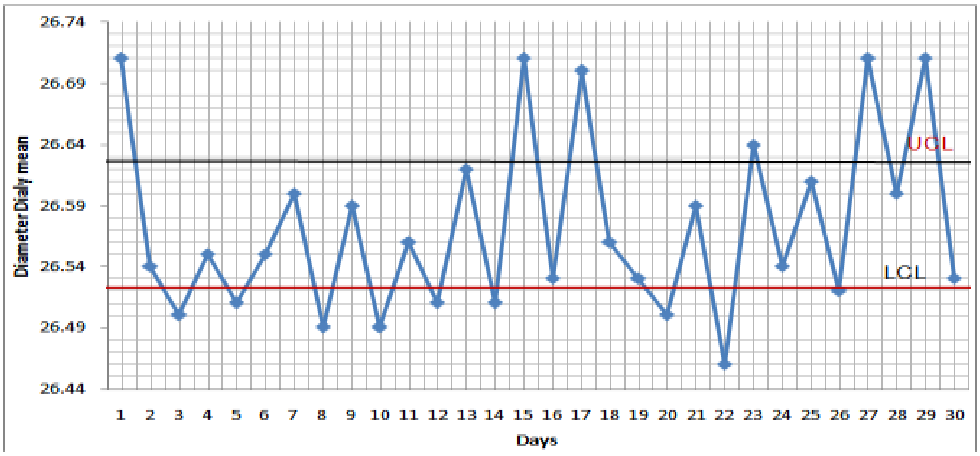

Figure 4.2 X-Chart (Diameter) for First Month

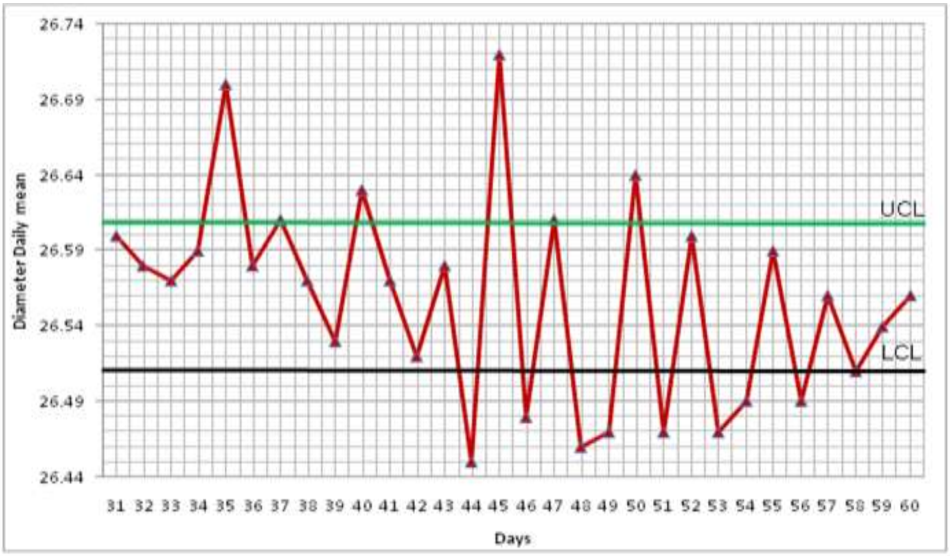

Figure 4.3 X-Chart (Diameter) for Second Month

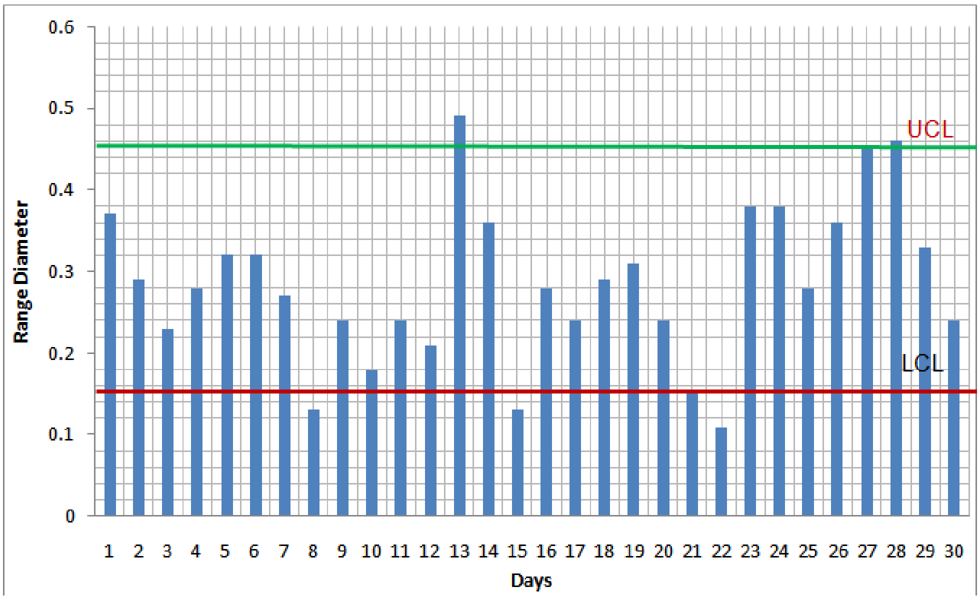

Figure 4.4 R-Bar Chart for First Month (Range Diameter)

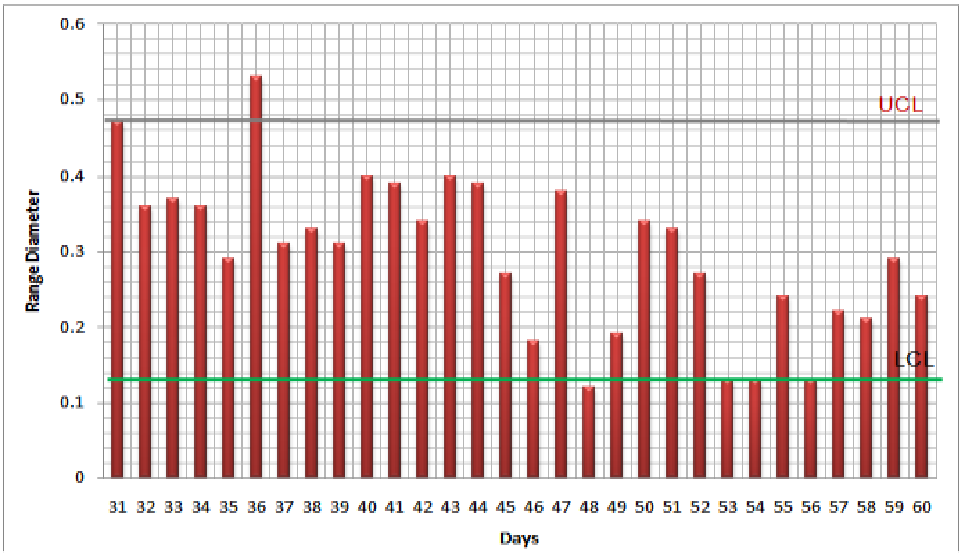

Figure 4.5 R-Bar Chart for Second Month (Range Diameter)

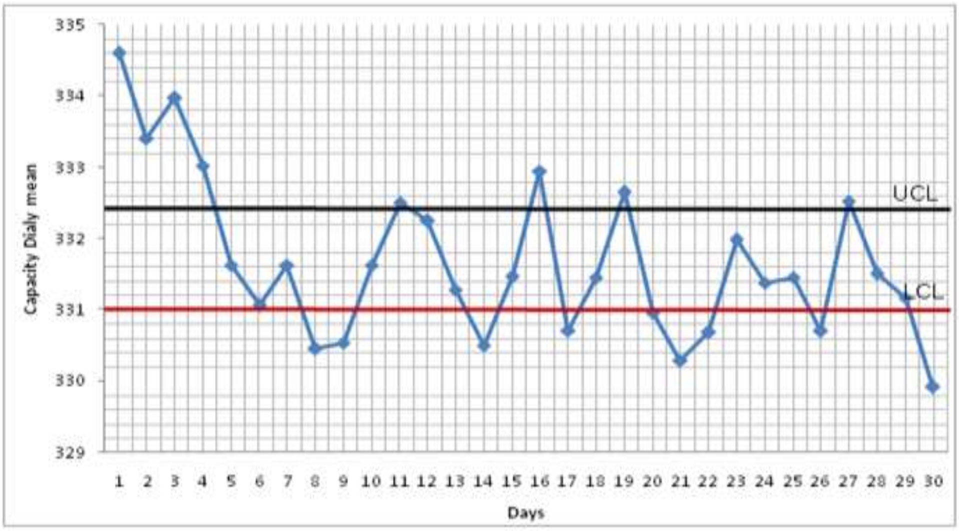

Figure 4.6 X-Chart (Capacity) for First Month

Figure 4.7 X-Chart (Capacity) for Second Month

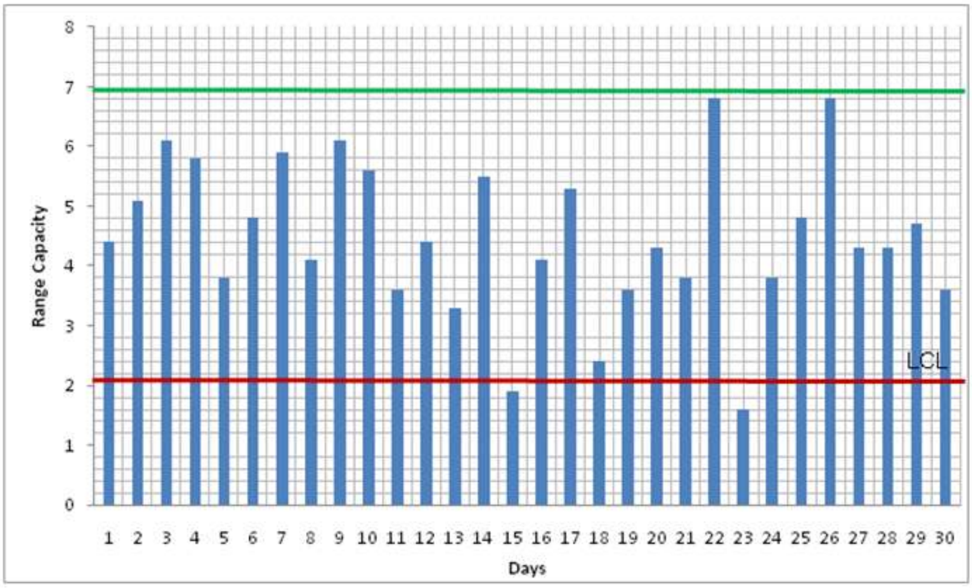

Figure 4.8 R-Bar Chart for First Month (Range Capacity)

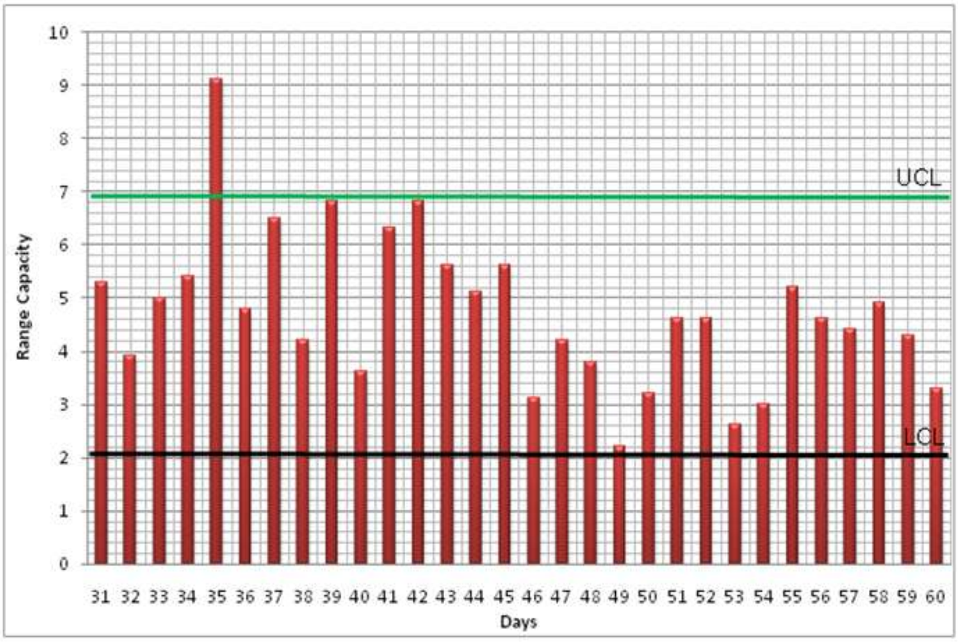

Figure 4.9 R-Bar Chart for Second Month (Range Capacity)

Generally, control charts serve mainly to guide designers and manufacturers to what can be produced in terms o5 tolerance. The upper lower control limits for the tread for the 2nd month's period are 26.62mm and 26,53mm for the 1st month and 26.61mm and 26.51mm for the 2"d month respectively. But the maximum and minimum allowable tolerance is 26.90 and 26.30 respectively. The process yield using the locking rings for 2nd month are 99-78% and 99.79% -respectively. Also, using the locking rings 0.214% and 0.207% of the products will not meet specifications for the I51 and 2^ respectively.

From Figure 4.6, the X-bar control chart for capacity shows that the mean for day 1, 2, 3 and 4 falls outside the control limits. This is due to some assignable causes and also the system is not -a perfect system. The capacity control chart for 1* month can be said to be in statistical control. Also from Figure 4.8, only the range for day 15 and 23 falls outside the control limit.

From Figure 4.7, the X-bar control chart for the 2nd month for capacity shows that the control charts is in statistical control. The upper and lower control limits for the first month are 332,38ml and 331.00ml respectively for capacity. But the maximum and minimum allowable tolerance for capacity are 334,6ml and 325.4ml respectively. The process is competitive, it must be emphasized here that for a given product specification, process capability index may not be constant over a period of time as the product range tends to show an inverse behavior with the process capability (Cp). When Cp was 1.36 for the 1st month, the product range mean was 0.285 and when Cp was 133 the range mean was 0.297 for the 2nd month for Diameter locking rings. When Cp was 1.33 for the 1st month, the product range mean was 4.487 and when cp was 1.26 the range mean was 4.737 for the 2nd month for capacity.

V. CONCLUTION

5.1 Conclution

Conclusively, product specification should be what is feasible in terms of process capability index, quality and cost, Tighter product tolerance means more high tech machineries, higher employee skills, high cost of production as cost of production is related to quality.

REFERENCES

[1]. Besterfield, RD. (1986), "Quality Control. New Jersey, Vol. 3, pp. 85-100,
[2]. Bhote, R, K. (1988), "Process Analysis", Journal of Quality Technology. Vol. 32, No. 4, October, 2000.
[3]. Chase, K. W. and Magleby, S. P. (1994), Generalised 3-D Tolerance Analysis of Mechanical Assemblies with Small Kinematics Adjustments. ADCATS Report No. 94, Vol. 2.
[4]. Degamo, P. (1974), "Materials and Processes in Manufacturing* Company Inc. New York, pp, 50-75,
[5]. Don, W. |1999(, Process Capability Studies. Available at; http://dsmar.com/iidfmes/CPK.pdf [April 13th 2009],
[6]. EHow Business Editor. How to conduct process capability studies. Available at: http://www.ehow>com/how jApril !3lK 2009].
[7]. Hald, A. (1952), Statistical Theory with Engineering Application"1 John Willey and Sons, New York, pp. 105-117.
[8]. Jerusp, P. (1985), "The Value of Continuing Improvement*, IEEC Conference on Communication.
[9]. Kane, K. K. (1986), "Manufacturing Process*. Journal of Zhejiang University Science. Vol. 4, pp 22-30.
[10]. Matthew, C, (20051, Process Capability Study of a Glass Industry. Coca-Cola glass container production, Ughelli - Warri,
[11]. Melissa, Tata, M. and Anna C, Thornton (1999). Process capability database usage in industry. Available at; http://lean. mit.edu/publications/cat view/99-resentations/73-conference-papers/361-1999-confererice-papers
[12]. Morrison, H. O. (2001), "Manufacturing Process"- "Conference Programme National Manufacturing Week".
[13]. Nelson, C. (1967), "Mean Square Error. A Useful Tool for Statistical Process .'Management", Amp Journal of Technology Vol. 1. 2 November, 1992,
[14]. Rao, M. F. (1995), "Indian Journal of Statistics, 1995 Vol. 57 Series B. Pt 2.
[15]. Rojerf F. (1996), "Discovery Advanced Mathematics Statistics". Bob/Harper Collins Publishers. Management Objectives with Quality Function, pp.15-25.
[16]. Roslund, J, L, (1989), "Evaluating Management Objectives with Quality Function". Quality Progress pp. 45-49,
[17]. Suozzi, T. {19*30}, Marc's Elsmar Cove Forums, "General Quality Management Systems and Environmental', pp. 113-115,
[18]. Taguchi, G. (1986), "Introduction to Quality Tokyo". Asia Productivity Centre, pp 5-20.
[19]. Turner, P. (1990), Is an out of specification product really out of specification product? Quality Progress, pp. 57-59
[20]. Xie, M. Goh, T. N, Wik, Lund, H. and Tang, X, Y. (2000), "Statistical Monitoring and Control of Tool Wear Processes'1. International Journal of Reliability, Quality and Safety Engineering. Vol. 7, No. 4, 331-340,
[21]. Xie, M. Tsu, K. L. Goh, T. N. and Cai, D. Q, (2000), "Manufacturing Process". International Journal of Production Research. Vol. 40, No. 10, 2367-2377.
[22]. Weiss and George, J. Saad, (1994), "NASA Glenn Research Centre, Aerospace Frontiers". Vol. 4 Issue 8, August 2002,
[23]. Wikipedia, Process_capability free encyclopedia available at http://enA\wikipedia.org/wikiy [April 13th 2009].

Douglas,P .O "Process Capability Study Of West African Glass Industry Plc, Port Harcourt, Nigeria "American Journal of Engineering Research (AJER), vol. 7, no. 11, 2018, pp.290-303