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(RESEARCH ARTICLE)

Appraisal of injection molding systems: A statistical approach

Ifeyinwa Faith Ogbodo [1], Chukwutoo Christopher Ihueze [2], Ogbodo Emmanuel Utochukwu [3] and Christain Emeka Okafor [4]

[1] *Department of Industrial & Production Engineering, Nnamdi Azikiwe University, Awka, Nigeria.*
[2] *Department of Electronics & Computer Engineering, Nnamdi Azikiwe University, Awka, Nigeria.*
[3] *Department of Mechanical Engineering, Nnamdi Azikiwe University, Awka, Nigeria.*

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Abstract

The deployment of statistical process control (SPC) in manufacturing environments is a prominent global phenomenon. Statistical Process Control is largely used in industries for monitoring the process parameters. It is a standard method for visualizing and controlling processes on the basis of measurements of randomly selected samples. SPC was used to evaluate the quality of production of five sample products from Injection mould system for years 2012 and 2014. This paper presents a rapid method for quality appraisal using Statistical Process Control to analyse quality of production during corrective and preventive maintenance of Innoson Injection mould system. SPC was used to visualize and control processes of the Injection mould system for 2012 and 2014 on the basis of measurement of randomly selected sample of five product. SPC used mean, standard deviation and range to detect variations in the process so that it can be controlled. SPC was used to evaluate the quality of defective production during corrective maintenance in 2012. Quality of defective production during preventive maintenance in 2014 was also monitored and analysed. The data collected from the production personnel was used to adjust the process to achieve the desired results. Those results were dependent on customer requirements, efficiency, quality, and reliability. Statistical Process Control (SPC) is a powerful collection of problem-solving tools useful in achieving manufacturing process stability and improving capability through the reduction of variability. Charts were used to determine the actual capability of production process, guide modifications for improving the output quality of process, and monitor the output. The monitoring function shows the current status of output quality and provides an early warning of deviation from quality goals. The key to quality is to detect when the process goes out of control so that we can correct the malfunction and restore the control of the process. SPC in 2012 during corrective maintenance of the system, shows out of control reflecting excessive defective products. While SPC, in 2014 during preventive maintenance of the system, shows in control for the X, S and R charts, depicting reduce defective products. In this paper need of SPC to analyse quality of production during corrective and preventive maintenance of Innoson Injection Mould system, by SPC as a quality control tool is discussed.

Keywords: Upper Control Lower; Lower Control Lower; Statistical Process Control; Injection Molding Systems; Continuous Improvement; Production Capability.

1. Introduction

Statistical Process Control (SPC) is a procedure for open or closed loop control of manufacturing processes based on statistical methods. This procedure helps in monitoring the process behavior. It is a standard method for visualizing and controlling processes on the basis of measurements of randomly selected samples. The main objective of SPC is to ensure that the planned process output is achieved and the related customer requirements are fulfilled. In this process control randomly, some parts are taken from the manufacturing process and then their characteristics are measured and shown on the control charts. Statistical indicators are determined from the measurements and used to evaluate the

*Corresponding author: I.F Ogbodo.

current status of the process. If required, the process is rectified with some appropriate actions. Reliability of system precedes its products quality, in the present world of continually increasing global competition it is imperative for all manufacturing and service organizations to improve the quality of their products. Quality has been defined in many ways (Gejdos, 2015). The American Society for Quality Control (1978) defined quality as the totality of features and characteristics of a product or service that bears on its ability to satisfy given needs. The quality of a product has always been of interest to the provider and customer. Quality is as old as Industry itself. In the ages before the industrial revolution, good craftsmen and artisans learned quickly through

intimate contact with their customers that quality products meant satisfied customer, and satisfied customer meant continued business. However, with the industrial revolution, came the mass production by people who rarely interacted with customers. As a result, although cost decreased, the emphasis on quality also decreased. In addition, as the product made and the service provided became more complex, the need for a formal system to ensure the quality of the final product and all it component became increasingly important. In modern firms, the quality of their product is dependent on a number of factors such as the organization and control of the firm's employees, and more technical perspective, true progress toward improving and monitoring quality on a mass scale did not begin until the advent of statistical quality control usually control, SPC. SPC refers to the statistical techniques used to control or improve the quality of the output of some production or service process. Shewhart Control Chart is a graphical device for monitoring a measurable characteristic of a process of showing whether the process is operating within its limits of expected (Azizi, 2016). Most products, even very simple ones, have many characteristics or dimensions, possibly correlated, that affect their quality, for example, a nail is defined by its length, diameter, hardness etc. Quality control can be considered from two orientations: we can take a product or a process perspective.

The degree to which other factors exist in a product can be subjective. Grewal and Gupta (2005) suggested that quality is a fundamental, inherent property of an object, an absolute; our interactions with an object provide us with both the objective and subjective measures of that quality. There are many definitions of quality in the literature. Manus (2001) stated that quality is fitness for use. Mahesh and Prabhuswamy (2010) defined quality according to multiple perspectives, including that of production workers, management, consumers, etc. Ramirez (2015) defined total quality as a concept that entails adding value, beyond merely satisfying consumers, as a consequence of production. Gupta (2006) listed eight product dimensions by which quality can be judged. Each dimension provided a different classification of observable product aspects that can be measured and controlled, such as features, reliability, and performance, among others. Both Shewhart (1931) emphasized that quality is customer defined. Companies must study the customer and take their needs into account when they design and manufacture their products. Halim and Jiju, (2014) taught that quality has many aspects, all of which must be accounted for in a definition of quality. Ultimately it must be defined in terms of customer satisfaction, which is not static. Taguchi and Wu (1979) defined quality as the value lost by society when defects occur in a product characteristic. Crosby (1979) definition was less ambiguous. He taught that quality is conformance to specifications. Bharatendra (2008) classified quality definitions according to whether they were primarily focused on product characteristics or on customer satisfaction. Other themes running through the various definitions are that quality is abstract, people perceive it in relative terms, it can be represented using substitute design specifications, and it affects many stakeholders (e.g., production workers, management personnel, consumers, and society at large). Throughout the rest of this review and during the study, the term quality will be used in the sense that it is inherently realized in a product and that indicators of quality can be based on both objective specifications and subjective impressions, each of which can be defined from the perspectives of multiple concerned parties. Attainment of quality objectives can be determined by measuring conformance to specifications and measuring and/or interpreting subjective reactions. The term product will be used in reference to any combination of goods, services, and consumables. Manus (2001) lent credence to this definition, suggesting that no good or service is completely one or the other. They suggested that when we interact with something, there are both physical and interpersonal aspects. For example, our satisfaction with a car is derived from objective performance measures, subjective impressions (look, feel, etc.) and the service associated with it (e.g., interactions with sales and service personnel). Satisfaction with a hotel visit, which is mostly considered a service, is also affected by the physical facilities. Thus, product will be used to denote the total package of goods and services an organization delivers to the customer and/or user.

A number of researchers have published research papers on the topic of SPC. Today companies invest on statistical process control (SPC), where they seek to measure key values in the manufacturing processes, to maintain the quality in the products (Attaran, 2000). The problem is that the measurement of these values can be affected by the expertise of the staff because of poor training, a high staff turnover, or because of the complexity of the process. For this experiment two groups of young engineers were given a set of instructions to do a quality process measuring. On one team a manual instruction was provided and on the other team an application of augmented reality where the subject can watch on site the instructions on real time of the process. With the analysis of the results it was determined that the group with the augmented does the process up to 30% faster. Ihueze and Ogbodo (2017) studied that, this integration enhanced the productivity performance, evaluate production productivity by continuously improve the equipment efficiency and process control in tiles manufacturing industry. OEE is indicator to measure the equipment efficiency. Analysis and efficiency improvement are carried out using Define, Measure, Analyze, Improve and Control (DMAIC). SPC is suggested as monitor function for evaluating the process quality performance and the seven basic tools are used to tackle the manufacturing process variations (Antony and Taner, 2000). AM is applied in the glazing line to improve the machine efficiency by giving more responsibility and authority to the operators to do more improvement and preventative actions to their own machines. Result of the implementation of AM has successfully reduced 8.49% of the defect rates of glazing line from 14.61% to 6.12%. Machine breakdown time has been decreased from 2502 minutes to 1161 minutes whereas the OEE has been improved 6.49% from 22.12% to 28.61%. The tools of statistical process control, through which we can achieve continuous quality improvement. The advantage of these tools is that they can identify the effects of the processes that cause unnatural variability in processes that result of errors and poor quality. He concluded that SPC as a very effective tool in ensuring process stability and benefits of the use of SPC with DMAIC (Define, Measure, Analyze, Improve and Control) improvement model. This combination of tools is very suitable for achieving the desired objectives of quality improvement and efficient manner can help solve all tasks and problems of the process of quality improvement. Parmar and Deshpande (2014) concluded from case studies that the SPC techniques can give significant improvement to the quality.

These tools and techniques are simple to implement, and it needs top management involvement and employee support. In this paper it has been found that the SPC tools can be applied to different products for reducing the defect and are used globally to improve quality. SPC seems to be a collection of statistically based problem-solving tools. Benneyan and Chute, (1993) investigate SPC is applied in the food industry with huge benefits in the business to diverse stakeholders. SPC implementation in the food industry is beneficial and guidelines relating to SPC implementation in the food industry has resulted in a slow adoption. Although there are limitations and barriers impeding the implementation, if the implementation was done correctly and greatly facilitated, SPC can be a versatile technique for managing quality improvement in the food industry and sustaining the quality of food products. Gupta (2006) found that statistical process control (SPC) techniques in the automotive industry is offering customers the widest and latest range of sealing solutions. SPC analysis may easily help in improving the efficiency of the manufacturing process thus decreasing the number of defective products, thus saving a lot of re-work cost and valuable time. For each specific product the suggested preventions can considerably decrease the loss to the industry in terms of both money and time. Although, improvement in rejection level of all the other products of the industry is noticed, shocker seals were the main concern because the rejection level of this product was more than 9.1%. After implementing the required suggestions /recommendations for shocker seals, it is found that process capability is improved and it is greater than required. Mahesh and Prabhuswamy (2010) illustrates the step by step procedure adopted at a soap manufacturing company to improve the Quality by reducing process variability using Statistical Process Control. Span of one year, many easily executable Remedies were implemented. Then the entire study was repeated again for the production lines. Post implementation study revealed that defects rate drastically came down thus reducing the process variability. Ihueze and Onyechi (2011) established the extent of control chart effectiveness and reliability in ascertaining four parameters, viscosity, PH, specific gravity and solid content of Peatone green emulsion paint. It was measured using control charts, X- chart, R- chart and S-chart, to establish control limit for each of the parameters, and was observed that both theoretical process capability and actual process capability is less than unity respectively, thus the production process is therefore out of control and the process must be stopped for proper appraisal of the process for assignable causes of variation. Statistical Process Control (SPC) is an effective statistical tool used to prevent defects on a cigarette-manufacturing company in Nepal. The research was carried out on three cigarette-making machines, i.e., 01, 02 (plain makers) and 09 (filter cigarettes with premium brands), which have high variability in circumference. The initial data were taken on all three machines, and then special causes were eliminated. After eliminating special causes, the CP (process capability indices) was increased for Maker-02 from 0.343 to 0.709 and for Maker-09 from 0.521 to 1.044. Thereafter, several common causes were identified and eliminated, which resulted in an increase in CP (process capability indices) for Maker-02 up to 1.0567 from 0.343 and for Maker-01, up to 1.0372 from 0.717.

Other recommendations and suggestions for preventive as well as corrective action were also made based on Failure Mode and Effect Analysis (FMEA). Bharatendra and Rai (2008) concluded that using SPC & control charts, out-of control situations are reduced from over 66% to about 4%. When a major quality problem faced by tea packaging units is control of weight variation in the tea packets. When the weight variation in tea packets is high, it is likely that buyers get underweight packets in some segments of the market and overweight packets in some other segments. Although an average consumer may not notice the difference, packet weight below certain limit may require the company to pay a substantial amount as fine to the government regulating agencies that conduct such audits. At the same time over weight packets constitute an additional loss to the company. Although SPC & control charts are well suited to help control such weight variation, their successful implementation at the machine requires a user-friendly approach for the operators who need to maintain it on a daily basis. Chandandeep and Gupta, (2006) found that Statistical Process Control is an effective means for controlling and improving the process quality and with the application of variable control charts, significant improvement has been experienced in terms of process capability indices and defective parts per million. PPM level in each case has reduced drastically which is a step to achieve the six sigma level. The company is a leading manufacturer of mechanical locking systems, door handles and security systems for automotive .The company is accredited with ISO 9001 and QS 9000 quality standards. The company has more than 200 employees and it is located in NOIDA. Major customers of the company in four wheeler segments are Ford, Telco, Fiat, Maruti, General Motors etc., and in two wheeler segments are Bajaj Auto, Kinetic Motors, LML, Yamaha, Hero Motors etc. The company has separate quality assurance department. Four critical variables i.e centre distance, hole location, groove location and diameter were selected on the basis of rejections due to them.

Obviously, Quality appraisal is an important feature in production using injection mould system, from the above we concluded that SPC is an effective tool of quality and process control in all type of industry not only manufacturing industry where quality and customer satisfaction is the major concern. The power of SPC lies in the ability to examine a process and the sources of variation in that process, using tools that give weightage to objective analysis over subjective opinions and that allow the strength of each source to be determined numerically. Studies that have examined quality problems in industries have focused almost exclusively on comprehensive quality management for quality measures. However the current study specifically considered quality appraisal of an indigenous company in Nigeria utilising Statistical Process Control to evaluate quality of production of five products.

2. Methodology

2.1. Statistical Process Control

Statistical Process Control (SPC) is a dynamic monitoring method where product quality is actively measured and simultaneously charted while manufactured goods are produced. SPC was used to visualize and control processes of the Injection mould system for 2012 and 2014 on the basis of measurement of randomly selected sample of five product. SPC used mean, standard deviation and range to detect variations in the process so that it can be controlled. Control charts were used in SPC for measuring the variation in the process and that can be continuously improved by the different techniques used in the SPC. SPC was used to evaluate the quality of defective production during corrective maintenance in 2012. Quality of defective production during preventive maintenance in 2014 was also monitored and analysed.

The data collected from the production personnel was used to adjust the process to achieve the desired results. Those results were dependent on customer requirements, efficiency, quality, and reliability. So SPC is a technique which is based on collection of data and used for attaining the desired result in the process. Statistical Process Control (SPC) is a powerful collection of problem-solving tools useful in achieving manufacturing process stability and improving capability through the reduction of variability. It may be used when a large number of similar items are being produced. The underlying assumption are that good items are produced when processes are in control with respect to target values, the historical production data used to calculate productivity factor is accurate and that production managers involved in the operations will be willing and able to learn the principle of evaluating production charts.

The main objective of SPC is to give a signal when the process changes, that is, when its mean moves away from the target value and/or its variability increases, also to indicate the points in time the process is in control or not, helps to rectify processes, to detect unusual variable taking place and helps in setting tolerance limit.

This paper presents a rapid method for quality appraisal using Statistical Process Control to analyse quality of production during corrective and preventive maintenance of Innoson Injection mould system. The data was extracted from the written records of production by the maintenance/store personnel during each day production. The records include the quantity of goods produced per day, the quality, the number of defective during and after corrective maintenance. Likewise during and after preventive maintenance of the system in order of 8 – hours shift. The data selected have relationship with quality appraisal of Injection moulding machine.

3. Results and discussion

3.1. Theory of Control Charts

Control chart is a graphic aid to detect quality variation in output from a production process. As opposed to the aim of acceptance sampling (to accept or reject products already produced), control chart helps to produce a better product. Charts have three main applications: (1) to determine the actual capability of production process (2) to guide modifications for improving the output quality of process, and (3) to monitor the output. The monitoring function shows the current status of output quality and provides an early warning of deviation from quality goals. The key to quality is to detect when the process goes out of control so that we can correct the malfunction and restore the control of the process. The control chart is the statistical method adopted in the analyses of production process control (Ihueze, Onyechi, 2011). From the statistical data gotten from Innoson Injection mould system, we have been able to establish the process control limits for the five sample products, using the X-chart, R-chart and S-chart. The following observations were made from the computations presented on charts of figure 1-4, as also reported by Ihueze and Ogbodo (2017).

Table 1 Evaluating Quality of Defective Production in Corrective Maintenance 2012

SAMPLE No	1	2	3	4	5	X	x/n = X	Max Min = R	X-x= D	$(X\text{-}x)^2$ D^2=S
JAN	43	42	46	49	43	223	44.6	7	178.4	31826.56
FEB	44	43	46	42	45	220	44.0	4	176	30976
MAR	46	47	47	44	45	229	45.8	3	183.2	33562.24
APR	42	43	40	45	43	213	42.6	5	170.4	29036.16
MAY	43	42	45	46	44	220	44.0	4	176.0	30976
JUNE	45	44	43	44	45	221	44.2	2	176.8	31187
JULY	42	43	45	46	42	218	43.6	4	114.4	30415.36
AUG	43	40	41	43	40	207	41.4	3	165.6	27423.36
SEPT	44	44	42	41	46	217	43.4	5	173.6	30136.96
OCT	42	42	44	41	44	213	42.6	3	170.4	29036.2
NOV	45	45	43	40	46	219	43.8	6	175.2	30695.0
DEC	45	45	41	44	42	217	43.4	4	173.2	299982
							523.4	50		
							12	12		336263

3.2. Models for statistical process control (spc), productivity improvement tool

For $\overline{X}$ Chart

Upper Control Limit, $UCL\overline{X} = \overline{X} + A_2\overline{R}$ (1)

Lower Control Limit $LC\overline{X} = \overline{X} - A_2\overline{R}$ (2)

For R Chart

Upper Control Limit, $UCL_R = D_4R$ (3)

Lower Control Limit $LC_R = D_3R$ (4)

For S Chart

Upper Control Limit, $UCL_S = \frac{B_4S}{2}$ (5)

Lower Control Limit $LC_S = \frac{B_3S}{2}$ (6)

Where $\overline{X}$, R and S Charts are control charts for variables. While A_2, B_3, B_4, D_3 and D_4 are obtained from Statistical Quality Control tables (`Deros et.al. 2010).

Using control charts for monitoring of the process this is called statistical process control (SPC).

3.2.1. Calculation of Control Limits (2014)

Average of all X values X = 4.8

Average of Range R = 3.92

Variance $= \frac{\sum(X-x)2}{n-1} = 462$

So the Variance S = 462

Using mean (X chart)

Applying the formular,

UCL = Upper control limits

$$= X + A_2R \quad (1)$$

LCL = Lower control limits

$$= X - A_2R \quad (2)$$

Where,

X is the average of all x values = 4.8
R is the average of Ranges = 3.92 and A_2 is the factor dependent on the sample size n = 5.
A_2 from control chart (n= 5) = 0.577 substituting A_2 into equations (1) and (2),

For UCL = X + A_2 R

Upper control limits = 7.06

For LCL = X – A_2R

Lower control limits = 2.54

(ii) For variables Ranges (R-Chart)

Applying the formula,

$$\text{For UCL} = D_4R \quad (3)$$

$$LCL = D_3R \quad (4)$$

Where D_3 and D_4 are values of n = 5 obtained from control chart 2, while R is the average of Ranges.

Therefore, D_3 (n=5) = 0

D_4 (n=5) = 2.114

R = 3.92

Substituting the values into equation (3) and (4)

For UCL = D_4R

Upper control limit = 8.2868

For LCL = D_3R

Lower control limits = 0

(iii) Using Variance (S chart)

Applying the formular,

$$UCL = B_4 \text{ X } \frac{S}{2} \quad (5)$$

$$LCL = B_3 \text{ X } \frac{S}{2} \quad (6)$$

Since variance is the square of standard deviation,

Where B_3 and B_4 are values of n = 5, obtained from control chart 2. While S is the variance. Substituting the values into equation (5) and (6)

For UCL = 501.3

Upper control limit = 501.3

LCL = 0

Lower control limit = 0

3.2.2. Calculation of Control Limits (2012)

Average of all X values = 43.6

Average of Range R = 4.167

$$\text{Variance} = \frac{\sum(X-x)2}{n-1}$$

So the variance S = 33232.6

Using mean (X Chart),

Applying the formular,

$UCL = X + A_2R$ (1)

$LCL = X - A_2R$ (2)

Where,

X is the average of all X values

= 43.6

R is the average of Ranges = 4.167 and A_2 is the factor dependent on the sample size n =5,

A_2 from control chart (n=5) = 0.5777

Substituting A_2 into equations (1) and (2)

For $UCL = X + A_2R$

Upper control limits = 46.00

For $LCL = X - A_2R$

Lower control limits = 41.20

For variables Range (R-chart), applying the formular,

For $UCL = D_4R$ (3)

$LCL = D_3R$ (4)

Where D_3 and D_4 are values of n=5 obtained from control chart 2, while R is the average of Ranges.

D_3 (n= 5) = 0

D_4 (n=5) = 2,114

R = 4.167 (Calculated)

Substituting the values into equation (3) and (4)

For $UCL = D_4R$

Upper control limits = 8.809

For $LCL = D_3R$

Lower control limits = 0

(iii) Using the variance (S chart), applying the formula,

$$UCL = B_4 \; X \; \frac{S}{2} \qquad (5)$$

$$LCL = B_3 \; X \; \frac{S}{2} \qquad (6)$$

Since variance is the square of standard deviation where B_3 and B_4 are values of n = 5 obtained from control chart 2. While S is the variance. Substituting the values into equation (5) and (6).

For UCL = 31929.7

Upper control limit = 31929.7

LCL = 0

Lower control limits = 0

Table 2 Control Chart Constants

X-bar Chart for sigma R Chart Constants S-Chart							
Sample Size=m	**A_2**	**A_3**	**d_2**	**D_3**	**D_4**	**B_3**	**B_4**
2	1.880	2.659	1.128	0	3.267	0	3.267
3	1.023	1.954	1.693	0	2.574	0	2.568
4	0.729	1.6.28	2.059	0	2.282	0	2.266
5	0577	1.427	2.326	0	2.114	0	2.089
6	0.483	1.287	2.535	0	2.004	0.030	1.970
7	0.419	1.182	2.704	0.076	1.924	0.118	1.882
8	0.373	1.099	2.847	0.136	1.864	0.185	1.815
9	0.337	1.032	2.970	0.184	1.816	0.239	1.761
10	0.308	0.975	3.078	0.223	.1777	0.284	1.716
11	0.285	0.927	3.173	0.256	1.744	0.321	1.679
12	0266	0.886	3.258	0.283	1.717	0.354	1.646
13	0.249	0.850	3.336	0.307	1.693	0.382	1.618
14	0.225	0.817	3.407	0.328	1.672	0.406	1.594
15	0.223	0.789	3.472	0.347	1.672	0.428	1.552
16	0.212	0.739	3.532	0.363	1.637	0.448	1.552
17	0.203	0.739	3.588	0.378	1.622	0.466	1.534
18	0.194	0.718	3.640	0.391	1.608	0.482	1.518
19	0.187	0.698	3.689	0.403	1.597	0.497	1.503
20	0.180	0.680	3.735	0.415	1.585	0.510	1.490
21	0173	0.663	3.778	0.425	1.575	0.523	1.477
22	0.167	0.647	3.819	0.434	1.566	0.534	1.466
23	0.162	0.633	3.858	0.443	1.557	0.545	1.455

24	0.157	0.619	3.895	0.451	1.548	0.555	1.445
25	0.153	0.606	3.931	0.459	1.541	0.565	1.435

Control chart constants for X-bar, R,S, Individuals (called “X” or “I” charts), and MRS (Moving Range) CAHRTS.

NOTES: To construct the “X” and “MR” Charts (these are companions) we compute the Moving Ranges as:

R_2 = range of 1st and 2nd observation, R_3 = range of 2nd and 3rd observation, R_4 = range 3rd and 4th observations, etc with the “average” moving range or “MR”-bar being the average of these ranges with the “sample size” for each of these ranges n = 2 since each is based on consecutive observations …. This should provide an estimated standard deviation (needed for the “I” chart) of

O = (MR-bar)/d_2 where the value of d_2 is based on, as just stated, m = 2.

Similarly, the UCL and LCL for MR chart will be: UCL = d_4 (MR-bar) and LCL = D_3 (MR-bar)

But, since D3 = 0 when n = 0 (or, more accurately, is “not applicable”) there will be no LCL for the MR chart. Just a UCL.

Table 3 Evaluating Quality of Defective Production in Preventive Maintenance 2014

Sample No	1	2	3	4	5	X	x/n=X	R	D	S
Jan	5	4	8	11	5	33	6.6	7	26.4	697.96
Feb	6	5	8	4	7	30	6.0	4	24	576
Mar	8	9	9	6	7	39	7.8	3	31.2	973.44
Apl	2	1	2	3	2	10	2.0	2	8	64
May	5	4	7	8	1	25	5.0	6	20	400
Jun	7	6	5	6	7	31	6.2	2	24.8	615.04
Jul	4	5	7	8	4	28	5.6	4	22.4	501.76
Aug	5	2	1	5	2	15	3.0	4	12	144
Sep	5	6	4	3	8	26	5.2	5	20.8	432.64
Oct	6	4	6	3	1	20	4.0	5	16	256
Nov	1	1	1	1	2	6	1.2	1	4.8	23.04
Dec	5	7	3	6	4	25	5.0	4	20	400

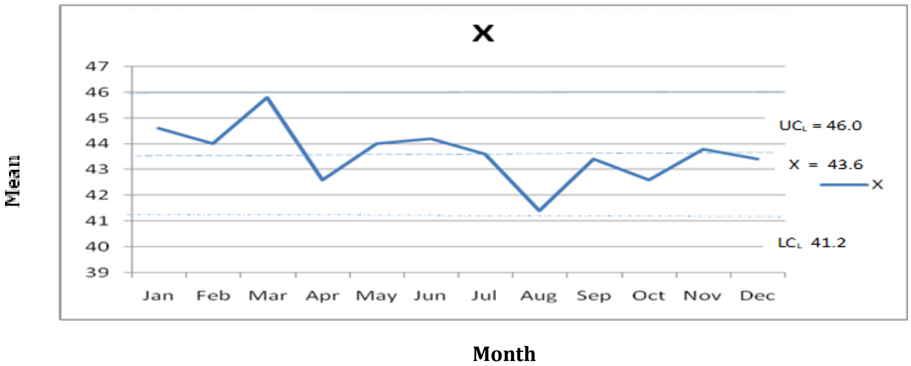

Figure 1 Statistical control charts for defective production in 2012

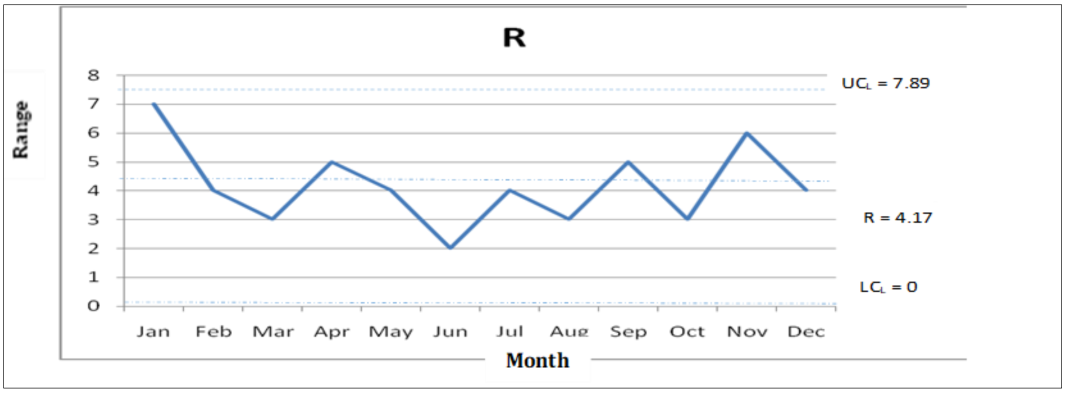

Figure 2 Statistical control charts for defective production in 2012

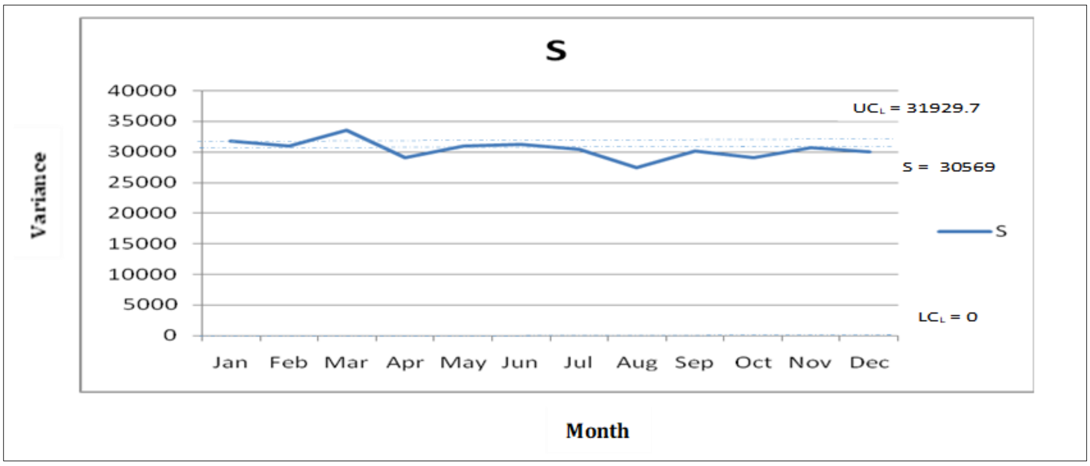

Figure 3 Statistical control charts for defective production in 2012 s-chart

3.3. Analysis of SPC monitor during corrective maintenance 2012

- For the X-chart in defective production 2012, it indicates that the process has highest defective production.
    - S-chart shows how the defective production varies, supporting excess defective production.
    - R-chart explains the process as high of defective production still. Management has to think of implementing preventive maintenance. The said charts were used to monitor the quality of defective production
- All through the year The said charts were used to monitor the quality of defective production all through the year 2012 and 2014

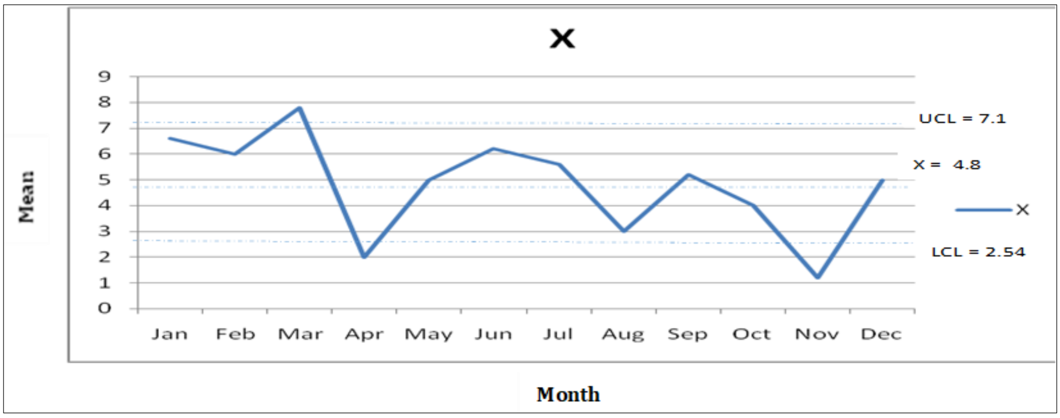

Figure 4 Statistical control charts during preventive maintenance in 2014, x-chart

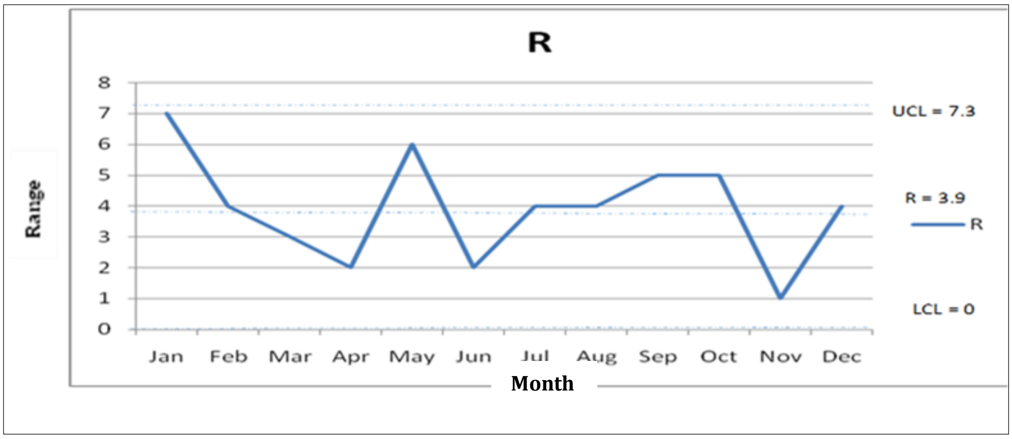

Figure 5 Statistical control charts during preventive maintenance in 2014, r-chart

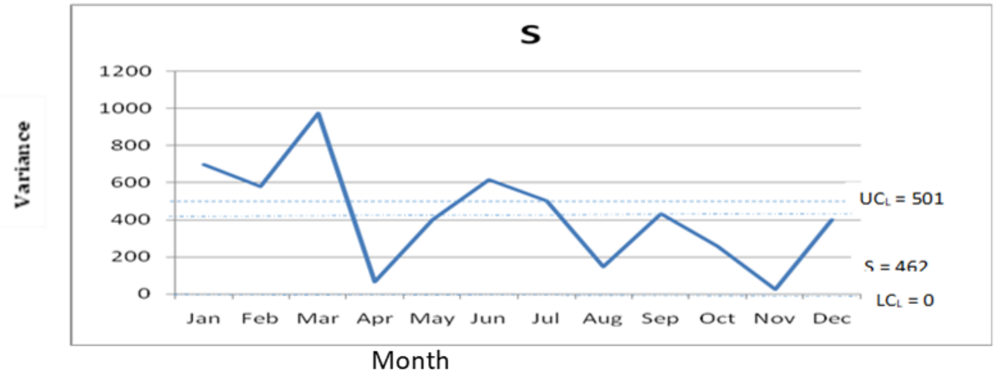

Figure 6 Statistical control charts during preventive maintenance in 2014, s-chart

3.4. Analysis of SPC monitor during preventive maintenance 2014

- X-chart showed out of control from defective production.
- R-chart showed implementation of preventive maintenance
- S-chart showed out of defective production control with its peak in March.
- Preventive maintenance was effectively done which reflected in the output.

4. Conclusion

Quality of production, places industries at competitive advantage over others. It could improve process performance by reducing product variability, improves production efficiency by decreasing scrap and rework. This leads to higher quality product by reducing variability and defects. This paper has presented a rapid method for quality appraisal using Statistical Process Control to analyse quality of production during corrective and preventive maintenance of Innoson Injection mould system. Quality of production improved greatly during preventive maintenance which lead to less defective products, which has in turn improved their overall business competitiveness, minimize rework and loss of sales. Likewise, it maintained a desired degree of conformity to design, eliminated any unnecessary quality checks and reduced the percentage of defective parts purchased from vendors, thus reduced return from customers. Furthermore, the information obtained from the study can be used for effective monitoring of production systems and helps to provide guidelines for quality control practices.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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