

Statistical Quality Control of Chemical Compositions of Rolled Products: A Case Study of the Light Section Mill of Ajaokuta Steel Company Limited

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Abstract

Statistical Quality Control (SQC) analysis deals with quantitative data; it is also a scientific method of analyzing masses of numerical data so as to summarize the essential features and relationship of data in order to generalize from the analysis pattern behaviour, particular outcome or future tendencies. This research work focused on the use of statistical quality control to determine the behaviours of the determined chemical compositions of rolled products from the Light Section Mill of the Rolling Mills of the Ajaokuta Steel Company Limited with a view to detecting and eliminating non-random (sporadic) variations in production process. The process monitored the performance of the chemical compositions of rolled products of medium carbon steel on a daily basis during the period of production from 29/04/06 to 29/05/06 for the production of rods from the Light Section Mill (LSM). The analyzed samples and data collected for critical characteristics were determined to ascertain if they shifted away from the purely random pattern (specified compositions). Ten samples were collected from the rolled products from the mill and were analyzed with a SPECTRO Analytical Instrument in the Quality Control and Materials Analysis in the Foundry Shop of the company, where the chemical compositions were determined as shown on the tables and they were also used to plot graphs for better understanding. Two control charts (\bar{x} and \bar{R}) were used to determine the performance and to indicate if the process remained in control and whether there are variations, these will serve as early warning system for information to the production engineers, the quality control officers and management of the mill that something odd has probably happened to the production process.

Keywords: Statistical; Quality; Control; Sporadic; Non-random; Performance; Chemical compositions

Introduction

Rolling consists essentially in passing a piece of metal between two revolving rolls. Biting of the metal and further rolling rely on friction between the rolled strip and the rolls. Rolling is one of the principal methods of plastic working of metals, employed to manufacture a great number of products such as squares, rounds and other simple and compound sections as rails, beams, sheets, pipes angles etc. Rolling is a continuous and regular process, an uninterrupted motion of the worked piece through the zone of deformation (between the rolls). This continuous process yield products of uniform structure and properties, as the conditions of working the piece is the same throughout the length of the product. The rolling process today consists of (a) manufacture of semi-product from an ingot and (b) manufacture of a finished item from the semi-product. Each of these stages is subdivided into the following operations: (i) Preparation of starting materials (ii) Heating the materials (iii) Rolling of the materials and (iv) Finishing of the product. The focus of this work is to use statistical quality control (SQC) approach to achieve a standard process of product which will assist the mills to control non uniformity by detecting and eliminating non-random (sporadic) variations as they arise while the process is operating [1].

The process could only be in control when some variations are sporadic. The process is monitored periodically by examining sample units of output. The process is to enable the process engineers, production engineers, quality control personnel and the management of the mill to determine when the measured data for the critical characteristics have shifted away from a purely random pattern; the process could be stopped immediately if the variations are moved away from position. The process could only continue as soon as the non-conformance is corrected. Control charts are the primary tool for

Statistical Quality Control (SQC), and the selection of control charts depends on the type of measurements that are to be used. In this work, the statistical quality control was used to control the chemical compositions of rolled products of medium carbon steel of 5SP grade. Inspection and process control were performed, in this research work a process control method was investigated, using statistical method for process control named statistical Quality control (SQC). Statistical Quality control (SQC) is the process used to detect and eliminate nonrandom (sporadic) variation in the conversion process of rolled products in the Light Section Mills (LSM) which is one of the mills in the Rolling Mills of the Ajaokuta Steel Company Limited [2].

Procedure and Methods

The study was conducted in the Light Section Mill of the Rolling Mill and in the Quality Control and Material Analysis of the Foundry Shop both of the Ajaokuta Steel Company Limited focusing on the use of Spectral Analytical Instrument for the determination of chemical compositions of collected samples. Ten samples were selected from the rolled products from the Light Section Mill of the Rolling Mills of the Ajaokuta Steel Company Limited during the period of investigation [3].

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Statistical Quality Control

Statistical quality control method is based on the control of variability of process variable, consideration of the chemical compositions of rolled products as process variable; samples of chemical compositions were periodically taken.

Control charts

Quality control charts were constructed for means and standard deviation (Sigma) value. A control chart has three horizontal lines drawn across the sample value. The Central Line represents the mean value (CL). The Upper Control Limit (UCL) represents the chemical compositions values of means + 3x Sigma. The Lower Control Limit (LCL) represents the chemical compositions means value of means-3x Sigma. The mean values obtained from various samples are plotted in diagrams. The aim of using these processes is to determine when the point or points fall within the band of UCL and LCL, the process is said to be under control on a statistical sense, when the points show trend of moving toward UCL or LCL, thereby indicating that the process may get out of control points falling outside the limits indicating out of control [4].

The statistical basis for control charts is as follows

It is assumed that the chemical compositions of large value of measurements should follow normal (Gaussian) distribution: Then if only 2% of the measured values fall outside the 3 sigma limit, the process is still believed to be outside the control limits in the control chart. This is considered as unacceptable condition for quality; if the mean value fall outside the limits, it indicates that the process is out of control [5].

Range (\bar{R} -chart)

It is defined as maximum value - minimum value. Range is related to sigma and therefore control chart can be drawn using range chart as was constructed with UCL and LCL as follows

Research Methods

The research was carried as shown below:

1. The chemical compositions of the collected samples from rolled products from the Light Section Mill were determined using the SPECTRO Analytical Instrument (SPECTRO-LAB) in the Foundry Shop. Before the samples were analyzed, they were first polished with a polishing machine using polishing papers (60 grants for steel products) [6-8]. The SPECTRO Analytical Instrument is an instrument that must be standardized every 8 hours or at the beginning of every shift by using the standard samples for the calibration of the equipment. Immediately the instrument was standardized, the ten samples collected from the rolled products were prepared and analyzed. These values as obtained (Tables 1-5).

2. The behaviours of the charts, which indicated perfect distributions without any of the points falling out of the upper and lower limits (Figures 1-10).

Control Charts

Two control charts were used where values from the samples were directly plotted. Various values were determined, where, the mean diameter of the samples determined and the range of the samples. The charts contained control limits (previously calculated using statistical principles) and the samples values were checked against the control

Chemical Compositions Of Carbon Content (Medium Carbon)							
1	2	3	4	5	Average		Range
0.355	0.356	0.345	0.318	0.353	0.3454		0.038
0.369	0.323	0.323	0.337	0.363	0.343		0.046
0.354	0.328	0.339	0.365	0.368	0.3508		0.04
0.336	0.332	0.338	0.376	0.36	0.3484		0.044
0.33	0.321	0.362	0.352	0.352	0.3434		0.041
0.345	0.33	0.335	0.378	0.393	0.3562		0.048
0.355	0.337	0.346	0.334	0.384	0.3512		0.047
0.381	0.355	0.34	0.37	0.377	0.3646		0.041
0.359	0.345	0.359	0.366	0.385	0.3628		0.04
0.333	0.36	0.357	0.359	0.321	0.346		0.038
					3.5118		0.423
				CL	0.35118	\bar{R}	0.0423
				UCL	0.37698	UCL	0.3643
				LCL	0.3258	LCL	0.3381

Table 1: Chemical composition of Carbon content.

Chemical Compositions Of Carbon Content (Medium Carbon)							
1	2	3	4	5	Average		Range
0.15	0.17	0.17	0.17	0.15	0.162		0.02
0.15	0.15	0.17	0.18	0.14	0.158		0.04
0.15	0.17	0.14	0.15	0.14	0.15		0.03
0.17	0.17	0.17	0.15	0.18	0.168		0.03
0.15	0.15	0.17	0.16	0.13	0.152		0.04
0.16	0.14	0.14	0.17	0.16	0.154		0.03
0.15	0.16	0.15	0.16	0.14	0.152		0.02
0.16	0.12	0.15	0.15	0.17	0.15		0.03
0.16	0.16	0.15	0.16	0.13	0.152		0.03
0.15	0.14	0.17	0.16	0.14	0.152		0.03
					1.55		0.3
				CL	0.155	\bar{R}	0.03
				UCL	0.173	UCL	0.053
				LCL	0.137	LCL	0.007

Table 2: Chemical composition of Silicon content.

Chemical Compositions Of Carbon Content (Medium Carbon)							
1	2	3	4	5	AVERAGE		Range
0.73	0.7	0.64	0.71	0.67	0.69		0.07
0.66	0.7	0.65	0.66	0.67	0.668		0.05
0.65	0.59	0.67	0.67	0.66	0.648		0.08
0.58	0.57	0.65	0.61	0.62	0.606		0.08
0.65	0.63	0.67	0.69	0.62	0.652		0.07
0.68	0.65	0.66	0.63	0.69	0.662		0.05
0.67	0.73	0.67	0.7	0.69	0.692		0.06
0.7	0.67	0.66	0.72	0.7	0.69		0.06
0.7	0.7	0.63	0.67	0.7	0.68		0.07
0.72	0.72	0.63	0.7	0.7	0.694		0.09
					6.682		0.68
				CL	0.6682	\bar{R}	0.068
				UCL	0.893	UCL	0.121
				LCL	0.443	LCL	0.015

Table 3: Chemical composition of Manganese content.

limits. There are normally two levels of control limit a Warning limit and an Action Limit. Action can only be taken if any plotted value is outside the control limits, action could then be taken to trace the specific cause of the variation and necessary corrections made, which assisted in reducing defects from rolled products that were not of the acceptable chemical compositions values. The charts were further used

Chemical Compositions Of Carbon Content (Medium Carbon)							
1	2	3	4	5	AVERAGE		Range
0.029	0.033	0.034	0.036	0.034	0.0332		0.007
0.033	0.034	0.032	0.028	0.028	0.031		0.006
0.033	0.028	0.034	0.037	0.033	0.033		0.009
0.031	0.032	0.024	0.031	0.027	0.029		0.008
0.025	0.03	0.028	0.028	0.025	0.0272		0.005
0.023	0.031	0.03	0.028	0.03	0.0284		0.008
0.03	0.03	0.032	0.033	0.036	0.0322		0.006
0.03	0.032	0.032	0.037	0.034	0.033		0.005
0.033	0.032	0.029	0.035	0.034	0.0326		0.005
0.033	0.03	0.034	0.034	0.035	0.0332		0.005
					0.3128		0.064
				CL	0.03128	\bar{R}	0.0064
				UCL	0.03818	UCL	0.0114
				LCL	0.02438	LCL	0.00141

Table 4: Chemical composition of Phosphorus content.

Chemical Compositions Of Carbon Content (Medium Carbon)							
1	2	3	4	5	AVERAGE		Range
0.041	0.044	0.044	0.045	0.040	0.0428		0.005
0.041	0.040	0.042	0.045	0.042	0.0420		0.005
0.039	0.043	0.048	0.048	0.044	0.0444		0.009
0.044	0.039	0.040	0.042	0.040	0.0410		0.005
0.04	0.043	0.037	0.037	0.036	0.0386		0.007
0.039	0.039	0.042	0.037	0.040	0.0394		0.005
0.044	0.043	0.045	0.041	0.042	0.0430		0.004
0.045	0.042	0.042	0.042	0.044	0.0430		0.003
0.043	0.048	0.041	0.048	0.041	0.0442		0.007
0.041	0.046	0.040	0.042	0.041	0.0420		0.006
					0.4204		0.056
				CL	0.04204	\bar{R}	0.0056
				UCL	0.048	UCL	0.010
				LCL	0.036	LCL	0.001

Table 5: Chemical composition of Sulphur content.

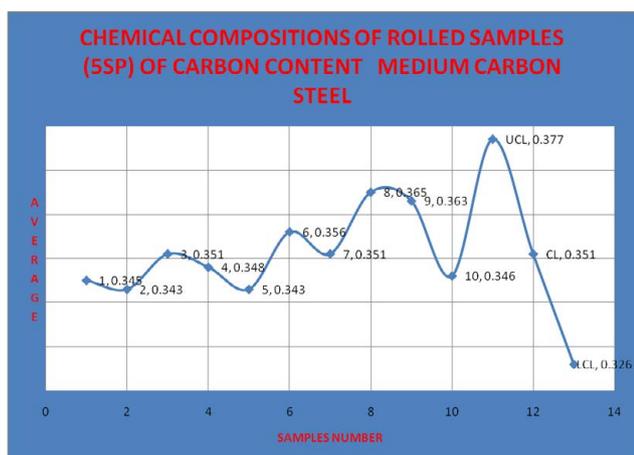


Figure 1: \bar{X} chart: Control chart for average of chemical compositions of carbon content of rolled products (5SP) of medium carbon steel.

to provide a visual means of distinguishing between the variability due to inherent causes (process in control) and the variability due to special causes (process out of control). The results obtained were used and can be understood by people with little or no statistical background [9,10].

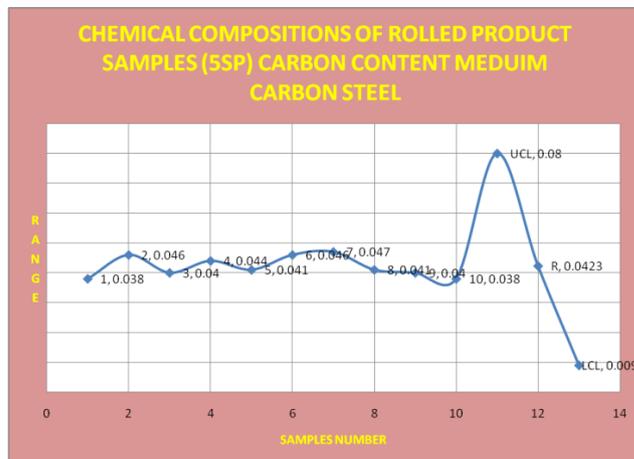


Figure 2: \bar{R} chart: Control chart for range of chemical compositions of carbon content of rolled products (5SP) of medium carbon steel.

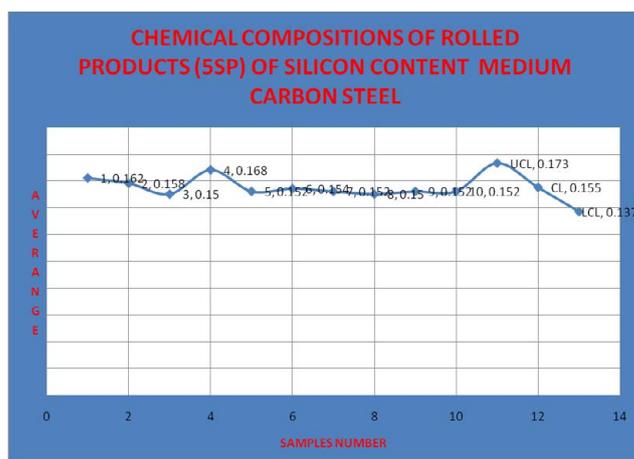


Figure 3: \bar{X} chart: Control chart for average of chemical compositions of silicon content of rolled products medium carbon steel.

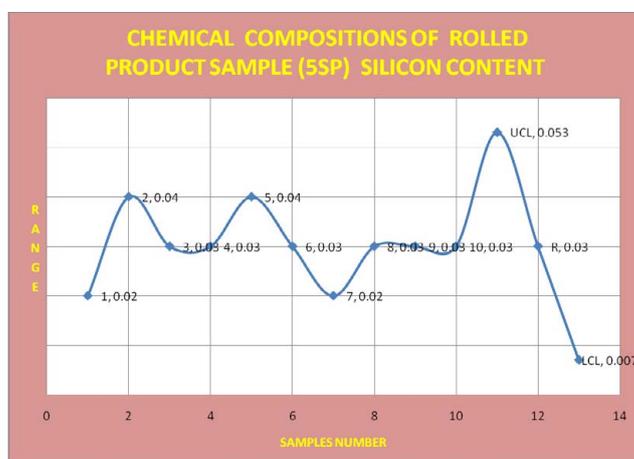


Figure 4: \bar{R} chart: Control chart for range of chemical compositions of silicon content of rolled products (5SP) medium carbon steel.

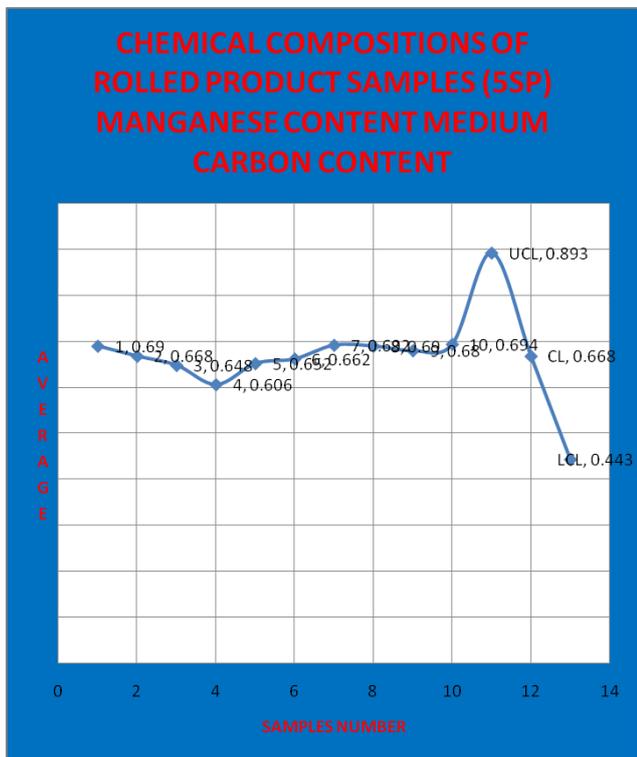


Figure 5: \bar{X} chart: Control chart for average of chemical compositions of manganese content of rolled product sample of medium carbon steel.

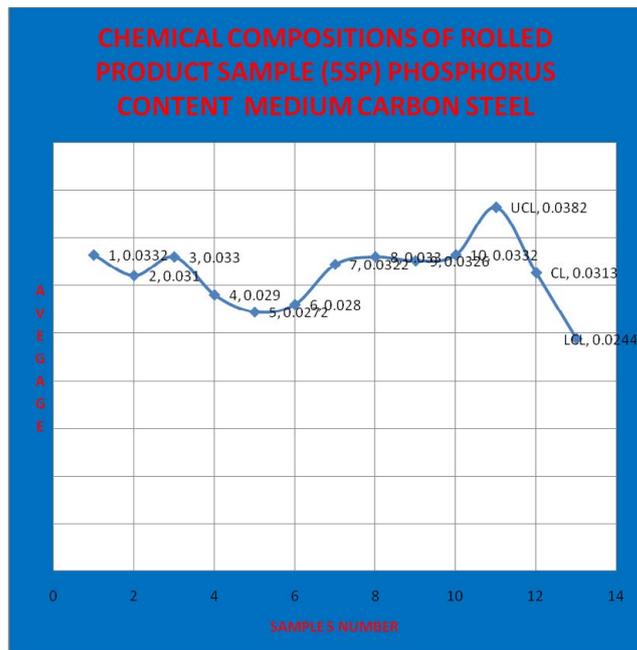


Figure 7: \bar{X} chart: Control chart for average of rolled product samples of phosphorus content medium carbon steel.



Figure 6: \bar{R} chart: Control chart for range of chemical composition of manganese content of medium carbon steel.

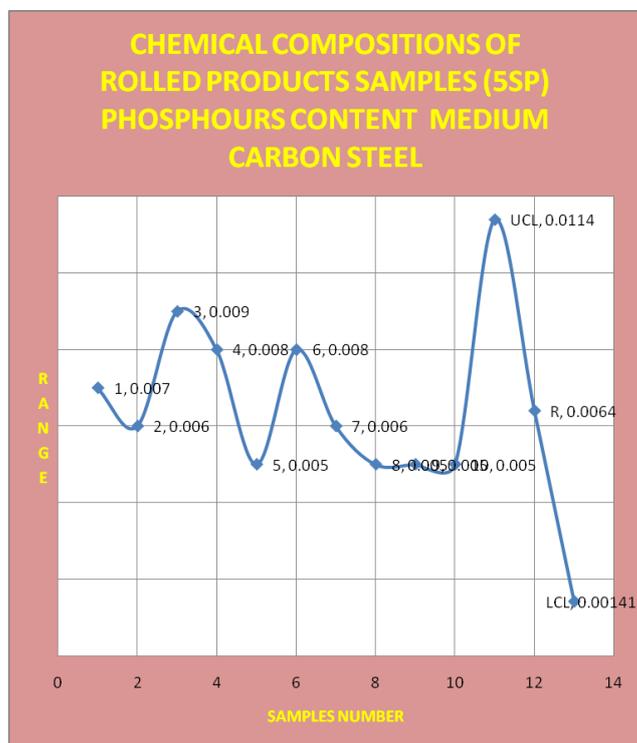


Figure 8: \bar{R} chart: Control chart for chemical composition of phosphorus content of medium carbon steel.

Two types of control charts were used in this research work are the \bar{X} Chart and the \bar{R}

The calculations for the \bar{X} control chart use

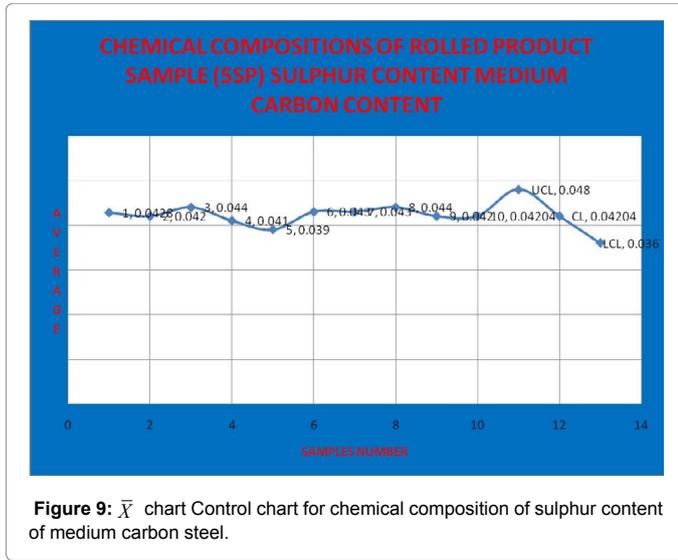


Figure 9: \bar{X} chart Control chart for chemical composition of sulphur content of medium carbon steel.

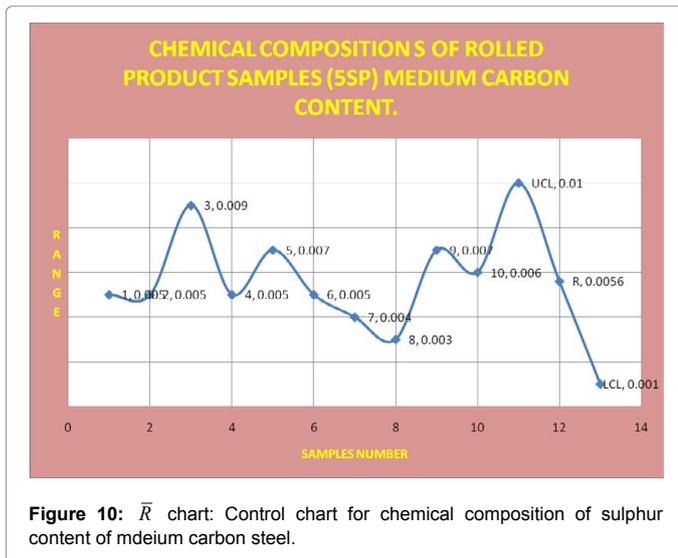


Figure 10: \bar{R} chart: Control chart for chemical composition of sulphur content of medium carbon steel.

$$\bar{\bar{X}} = \frac{\sum_{i=1}^n 1Xi}{n} \tag{1}$$

Which define the sample average \bar{x} , that is, the average of the samples units (for some variable measurement); the average $\bar{\bar{x}}$ of the sample averages, the standard deviation of the distribution of the sample averages and Upper Control Limit and Lower Control Limit

$$\bar{\bar{X}} = \frac{\sum_{j=1}^m 1}{n} \tag{2}$$

$$S\bar{x} = \sqrt{\frac{\sum_{j=1}^m (x_j - \bar{\bar{x}})^2}{m-1}} \tag{3}$$

$$UCL = \bar{\bar{x}} + K S\bar{x} \tag{4}$$

$$LCL = \bar{\bar{x}} - K S\bar{x} \tag{5}$$

Where X_i =Measurement for sample unit i

n =number of units in each sample

\bar{x} =Average of the sample units in sample j

m =number of samples

K =Constant, value of standard deviations ($K=3$)

$\bar{\bar{X}}$ Control chart

Central line $CL = \bar{\bar{X}}$

Upper Control Limit is $CL = \bar{\bar{x}} + 3S\bar{x}$ (6)

Lower Control Limit is $CL = \bar{\bar{x}} - 3S\bar{x}$ (7)

\bar{R} Control Chart

Central line $CL = \bar{R}$

Upper Control Limit $UCL = D_4 \bar{R}$, where D_4 for ten samples=1.78

Lower Control Limit $LCL = D_3 \bar{R}$, where D_3 for ten samples=0.22 [2]

$$\bar{R} = \frac{R_1 + R_2 \dots + R_n}{K} \tag{8}$$

$$\bar{\bar{X}} = \frac{\bar{X}_1 + \bar{X}_2 \dots + \bar{X}_n}{K} \tag{9}$$

$$\bar{X} = \frac{x_1 + x_2 \dots + x_n}{n} \tag{10}$$

$$\bar{X} = \sqrt{\frac{\sum_{i=1}^n 1Xi}{n}} \text{ Average } \bar{X} \tag{11}$$

$$\bar{\bar{X}} = \frac{\bar{X}_1 + \bar{X}_2 \dots + \bar{X}_n}{K}$$

$$\bar{\bar{X}} = \frac{\sum_{j=1}^m 1}{n} \tag{12}$$

$$\bar{R} = \frac{R_1 + R_2 \dots + R_n}{K}$$

$$S\bar{x} = \sqrt{\frac{\sum_{j=1}^m (x_j - \bar{\bar{x}})^2}{m-1}}$$

Where X_i =Measurement for sample unit i

n =number of units in the sample.

Presentation and Analysis of Data

To attain the aims and objectives of this study, all the data gathered from the analyzed chemical compositions of the rolled products from the Light Section Mill of the Rolling Mills were presented and analyzed. These rolled products are used in the construction industry, building industry and other industries that have to rods for reinforcement purposes etc.

Results and Discussions

Interpreting control charts for variables

It could be seen from the behavior of the figures that all the points on various graphs fell within the upper and lower control limits. With these results we were able to detect and monitored the variability in the production process, this was achieved by using two control charts

based on control limits. The standard deviation and simple ranges were calculated with the standard formula. These average values were plotted on the control charts. Also the \bar{R} chart, a control chart was used, in which the ranges were plotted. The \bar{R} chart is widely used in the industry because it is computationally simple and easy to understand.

The control limits were calculated using the equation below, along with the appropriate predetermined factors for ten samples D_3 (0.22) and D_4 (1.78) (Factors A_2 , D_3 and D_4 for \bar{X} chart and \bar{R} chart for three-standard-deviation control limits) [2]. From all the results we observed that all the points plotted fell within the Upper and Lower control limits.

The results implied that the chemical compositions of Carbon, Silicon, Manganese, Phosphorus and sulfur contents values of medium carbon steel as produced in the Light Section Mill of the Rolling Mills of the Ajaokuta Steel Company Limited, are of high standard and of good quality and can be used for the purpose for which they were intended for, be it in the construction industry, reinforcement purposes etc. The process should therefore be allowed to continue and more efforts must be made to sustain the trend and the behavior of the production process.

Conclusion

It could be concluded by saying that the use of statistical quality control process had helped in controlling the production processes of billets rolled into rods in the mill in which the chemical compositions of the billets produced confirmed with the specifications of grade 5SP has been produced from the Delta Steel Company Limited (DSC) Aladja in Delta State. All the values are all within the process control limits indicating that all the points are within the Upper Control Limit and Lower Control Limit.

This research will continue to be a meeting point for production engineers, the quality control and assurance personnel and the managements of the mill for better productivity. The process will further assist in monitoring and eliminating bad products, cobbles or undercut discovered in the production process which could be taken to the Foundry Shop as cropends (steel scrap) to commence the production process depending on the type of products to be cast which could be any grade of cast iron or steel products.

The quality of the products and the production processes were confirmed, which indicated how the products met the requirement, specifications and satisfied of the customers. The process indicated that the rolled products will be able to perform satisfactorily in the application for which it was intended for by the user, the performance of the products did not exhibit deleterious effect on it application. The process has to a great extent agreed and conformed with International Standard Organization (ISO) and that of Standard Organization of Nigeria (SON) has they have on several occasion confirmed these chemical compositions with their standard samples.

Finally, the use of the statistical quality control had assisted in detecting and eliminating non-random (Sporadic) variation in the production process and had also determined that the chemical compositions of rolled products from the Rolling Mills of the steel company confirmed with the certificates that accompanied the billets from the primary source of production Delta Steel Company Limited, Aladja, Delta State.

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