STATISTICAL QUALITY CONTROL OF CHEMICAL COMPOSITIONS AND HARDNESS VALUES OF GREY CAST IRON IN FOUNDRY SHOP – AJAOKUTA STEEL COMPANY LIMITED (ASCL)

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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 chemical compositions and hardness values of grey cast iron in the Foundry Shop with a view to detecting and eliminating non -random (sporadic) variations in production process. The process monitored the performance of the Chemical compositions and hardness values of grey cast iron periodically by examining sample units of output. The analyzed samples and data collected for critical characteristics were determined to ascertain if they shifted away from the purely random pattern. Ten samples were collected and analyzed with a SPECTRO Analytical Instrument in the Quality Control and Materials Analysis in the Foundry Shop of the Company, the chemical compositions were determined and the same samples were also used for hardness values which were also determined with the use of Brinell Machine in the Mechanical Repair Shop of the company. Two control charts (X and R) were used to determine the performance and to indicate if the process remained in control and where there are variations, these will serve as early warning system for the information of the management that something odd has probably happened to the production process.

Key words: Statistical, Quality, Control, Sporadic, Non –random and performance

1.0 INTRODUCTION

Foundry practice has become one of high specialized branch of Engineering that embrace many skill including those of the pattern marker, the molder, the core marker, planner and designers ,the smelters, fettlers and heat treatment, quality control and materials analysis, total quality management , the foundry men, the metallurgical Engineers and Metallurgists.

It is one of the basic intermediary industries complementing forging and machining processes through which metallic raw materials like pig iron, crop ends (steel scraps); Ferro-alloys could be processed, refined and shaped into new products.

The focus of this work is to use statistical quality control (SQC) approach to achieve a standard process of product which will assist the shop to control non uniformity by detecting and eliminating non-random (sporadic) variations as they arise while the process is operating.

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 shop 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 and hardness values (**Hardness** is related to the strength, durability, and toughness of solid substances, and in common usage the term is often extended to include those properties) of grey cast iron.

Although in foundries the quality control process involves two steps, Inspection and process control, in the case of this 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 non-random (sporadic) variation in the conversion process in the production of grey cast iron.

2.0 PROCEDURE AND METHODS

The study was conducted in the Foundry shop and Machine and Tool shopboth of the Ajaokuta Steel Company Limited with particular reference to the Quality Control and Materials Analysis section, focusing on the use of Spectrol Analytical Instrument for the determination of chemical compositions and test of the hardness values of the grey cast iron with the use of hardness testing machine known as Brinell Machine.

Ten samples of grey cast iron products were selected from the grey cast iron products as produced in the foundry shop of the Ajaokuta Steel Company Limited, where the samples were determined both for the chemical compositions and hardness values.

3.0 STATISTICAL QUALITY CONTROL IN FOUNDRY ENGINEERING

Statistical quality control method is based on the control of variability of process variable, consideration of the chemical compositions and hardness values of the casting as process variable, samples of chemical compositions and measured hardness valueswere periodically taken.

Hardness value is a critical characteristic of cast products in Engineering, but more emphasis is given to Foundry Engineering.The hardness values of five indentations were each taken on samples and the values were used for calculation. The means and standard deviation (Sigma) of these five indentations each were calculated.

3.1 Control charts: Quality control chart was 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. The upper Control Limit (UCL) represents the chemical compositions and hardness values of means + 3x Sigma

The Lower Control Limit (LCL) represents the chemical compositions and the hardness 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, whenthe 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.

3.2 The statistical basis for control charts is as follows

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

3.3Range (R-Chart) 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 .

4. 0 RESEARCH METHODS

The research was carried out by two methods as follows:

(a) The chemical compositions of the samples were determined using the Spectrol Analytical Instrument (Spectrol –Lab).

Before the samples were analyzed, they were first polished with the use of polishing machine using polishing papers (40 grants). The Spectrol Analytical Instrument is an instrument that must be standardized every 8 hours or at the beginning of every shift by using the standard samples.

Immediately the instrument was standardized, the ten samples of grey cast iron were prepared and analyzed. In the cause of the analysis, five sparks each were taken on the samples which covered the first three elements in the samples (i) Carbon content (ii) Silicon Content and (iii) Manganese content. These values as obtained are shown on the tables 1, 2 & 3.

(b) Brinell hardness machine was used to determine the hardness values of grey cast iron, these analyses were carried out at the Machine and Tool Shop of the Ajaokuta Steel Company Limited. The hardness values of the ten samples collected were determined with the use of Rockwell hardness tester on "C" Scale with diamond pyramid cone indenter.

A minor load of 10kg and a major load of 150kg and hardness value of 59.6 HRC as the standard block. Before the tests were carried out, the mating surface of the indenter plunger rod and the test samples were thoroughly cleaned by grinding the surface with polishing papers of 40 grants and the calibration of the machine was done using the standard block. The samples were placed on an anvil, which act as a support for the test samples.

Five indentations each on the samples were taken when the samples were analyzed. A minor load of 10kg was applied to the sample in a controlled manner without inducing impact or vibration and zero datum position was established, and then the major load of 150kg is then applied, the readings were taken when the large pointer comes to rest or show appreciably and dwell up to two (2) seconds .

The load is then removed by returning the crank handle to the latched position. The hardness value is read directly from the semi automatic digital scale. The reading of these hardness values in HRC Rockwell, and then a micrometer screw gauge was used in taking the readings and a standard hardness convectional table was used to convert the readings as indicated on table 4

5.0 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, the range of the sample, the proportion defects. The charts contained control limits (previously calculated using statistical principles) and the samples values checked against the control 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 production of scraps and rejects from the production process and products that were not of the acceptable chemical compositions and hardness values are not accepted.

The charts were further used 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.

Two types of control charts were used in this research work the R- Chart and the X-Chart

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

$$\bar{X} = \frac{\sum^{n}_{i} X1}{n} \quad \text{------------(1)}$$

Which define the sample average 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 $S_{\bar{X}}$ of the distribution of the sample averages and Upper Control Limit and Lower Control Limit

$$\bar{\bar{X}} = \frac{\sum^{m}_{j=1}}{m} \quad \text{-----------(2)}$$

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

$UCL = \bar{\bar{X}} + K\, S_{\bar{x}}$

$LCL = \bar{\bar{X}} - K\, S_{\bar{x}}$

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)

CHEMICAL COMPOSITIONS OF SILICON CONTENT

S/NO	1	2	3	4	5	AVERAGE		RANGE
1	0.88	0.86	0.86	0.85	0.86	0.862		0.03
2	0.85	0.84	0.85	0.86	0.87	0.854		0.03
3	0.87	0.86	0.85	0.84	0.87	0.858		0.03
4	0.85	0.83	0.81	0.82	0.83	0.828		0.04
5	0.86	0.85	0.86	0.87	0.84	0.856		0.03
6	0.85	0.84	0.83	0.82	0.84	0.836		0.02
7	0.82	0.83	0.83	0.85	0.84	0.834		0.03
8	0.84	0.85	0.86	0.87	0.85	0.854		0.02
9	0.85	0.87	0.85	0.85	0.84	0.852		0.03
10	0.86	0.87	0.88	0.86	0.87	0.868		0.02
						8.502		0.28
					CL	0.8502	$\bar{R}$	0.028
					UCL	0.9076	UCL	0.04984
					LCL	0.7928	LCL	0.00616

CHEMICAL COMPOSITIONS OF CARBON CONTENT

S/NO	1	2	3	4	5	AVERAGE		RANGE
1	3.08	3.07	3.06	3.08	3.07	3.072		0.02
2	3.04	3.02	3.03	3.01	3.02	3.024		0.03
3	3.03	3.05	3.04	3.06	3.05	3.046		0.03
4	3.04	3.05	3.06	3.07	3.05	3.054		0.02
5	3.03	3.05	3.07	3.06	3.04	3.05		0.04
6	3.09	3.07	3.06	3.08	3.05	3.07		0.04
7	3.07	3.09	3.05	3.09	3.07	3.074		0.04
8	3.07	3.09	3.07	3.04	3.08	3.07		0.05
9	3.05	3.06	3.09	3.07	3.09	3.072		0.04
10	3.09	3.06	3.05	3.07	3.05	3.064		0.04
						30.596		0.35
					CL	3.0596	R	0.035
					UCL	3.1076	UCL	0.0641
					LCL	3.0116	LCL	0.0059

$\bar{X}$ Control chart

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

Upper Control Limit is CL = $\bar{\bar{X}} + 3S\bar{x}$

Lower Control Limit is CL = $\bar{\bar{X}} - 3S\bar{x}$

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**

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

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

$$X = \frac{X_1 + X_2 + \ldots X_n}{N}$$

(a) $X = \frac{\Sigma^n_{i=1} X_i}{N}$ Average X

$$S = \sqrt{\frac{\Sigma^{n}_{L=1}(\overline{X}-X_i)^2}{n-1}}$$

Where X_i = Measurement for sample unit $_i$

n = number of units in the sample.

6.0 PRESENTATION AND ANALYSIS OF DATA

To attain the aims and objectives of this study, all the data gathered from the analyzed chemical compositions and hardness values of grey cast iron were presented and analyzed.

Table 1: Chemical composition of carbon content

CHEMICAL COMPOSITIONS OF MANAGANESE								
S/NO	1	2	3	4	5	AVERAGE		RANGE
1	0.615	0.614	0.612	0.615	0.615	0.6142		0.003
2	0.541	0.542	0.543	0.543	0.544	0.5426		0.003
3	0.755	0.754	0.756	0.757	0.755	0.7554		0.003
4	0.924	0.921	0.921	0.923	0.924	0.925		0.003
5	0.621	0.622	0.624	0.623	0.623	0.6226		0.003
6	0.605	0.604	0.606	0.603	0.604	0.6044		0.003
7	0.722	0.723	0.723	0.724	0.725	0.7234		0.003
8	0.495	0.496	0.497	0.498	0.496	0.4964		0.003
9	0.511	0.511	0.512	0.513	0.514	0.5122		0.003
10	0.921	0.922	0.923	0.924	0.925	0.923		0.004
						6.7192		0.031
					$\overline{CL}$	0.67192	$\overline{R}$	0.0031
					UCL	1.06192	UCL	0.005518
					LCL	0.28192	LCL	0.000682

Table3: Chemical Composition of manganese

HARDNESS OF GREY CAST IRON								
S/NO	1	2	3	4	5	AVERAGE		RANGE
1	780	712	780	745	780	759.4		68
2	780	780	745	780	745	766		35
3	712	712	712	712	780	725.6		68
4	780	780	712	712	780	752.8		68
5	780	745	745	780	759	761.8		35
6	745	712	712	780	702	730.2		68
7	712	780	712	780	712	739.2		68
8	780	745	745	780	745	759		35
9	712	712	745	745	712	725.2		33
10	745	780	745	745	780	759		35
						7478.2		513
					$\overline{CL}$	747.82	$\overline{R}$	51.3
					UCL	800.6	UCL	91.314
					LCL	695.05	LCL	11.286

Table 2.Chemical Composition of Silicon Content

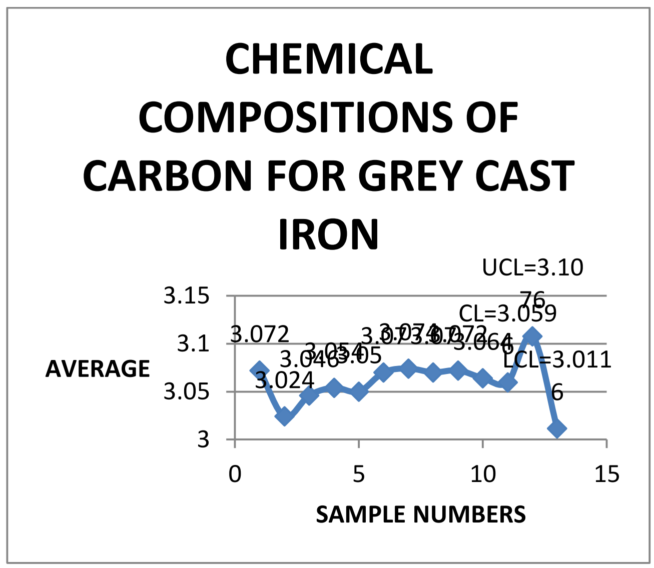

Figure 1.0 X chart: Control chart for average of chemical Compositions of Carbon content of grey cast

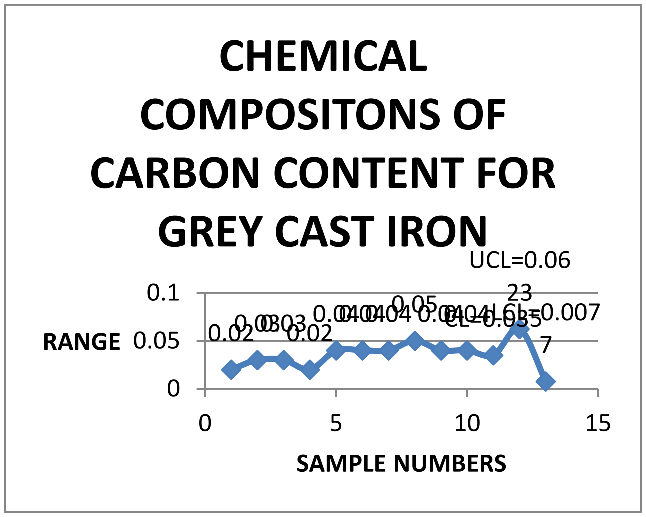

Figure 2.0 R chart: Control chart for range of chemical Compositions of Carbon content of grey cast iron.

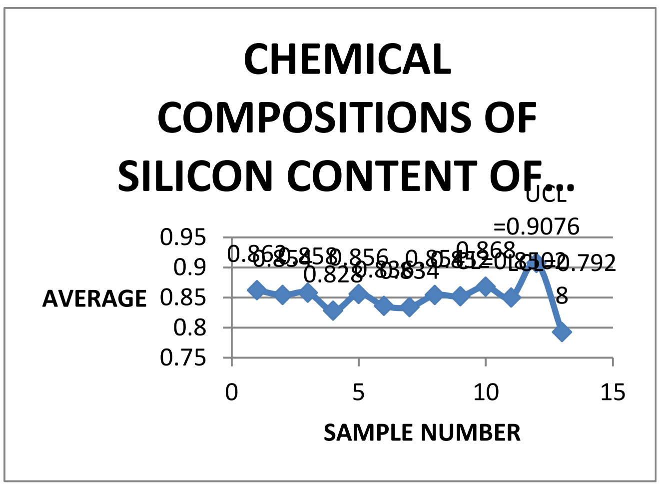

Figure 3.0 R chart: Control chart for average of chemical Compositions of Silicon content of grey cast iron

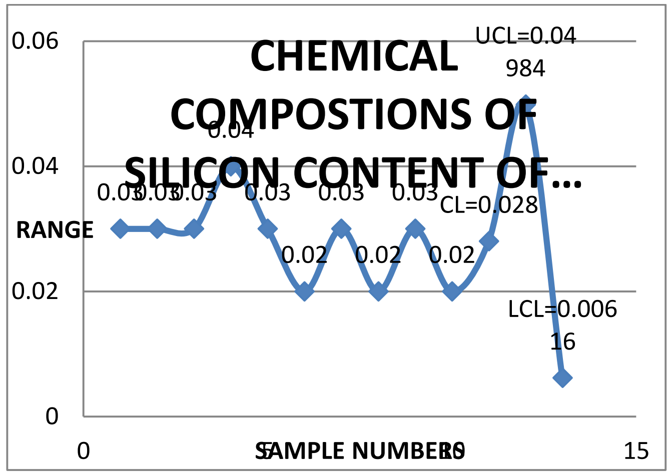

Figure 4.0 R chart: Control chart for range of chemical Compositions of Silicon content of grey cast iron

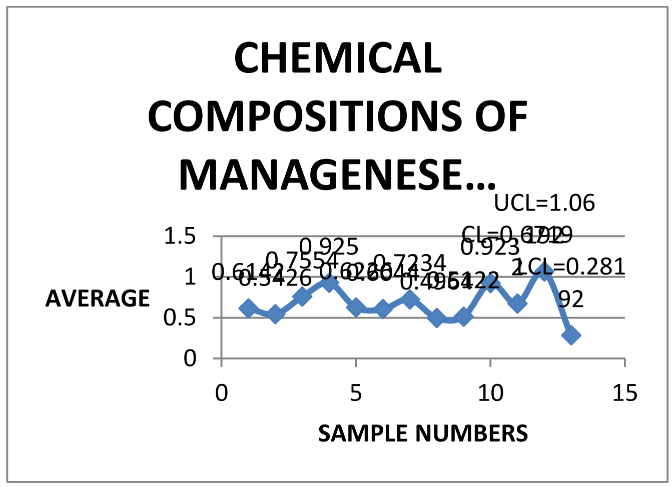

Figure 5.0 X chart: Control chart for average ofchemical Compositions of mangenese content of grey cast iron.

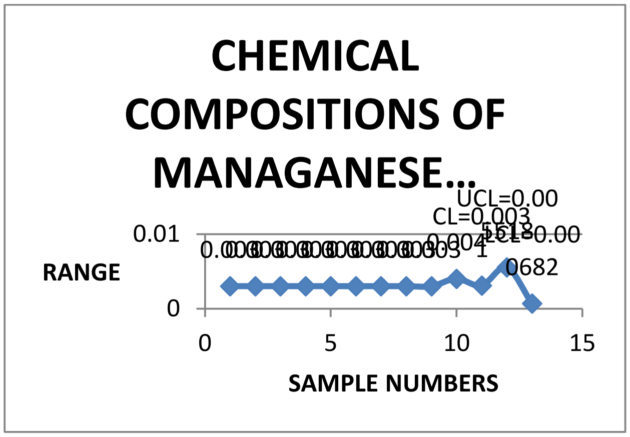

Figure 6.0 R chart: Control chart for range of chemical Composition of managanese content of grey cast iron.

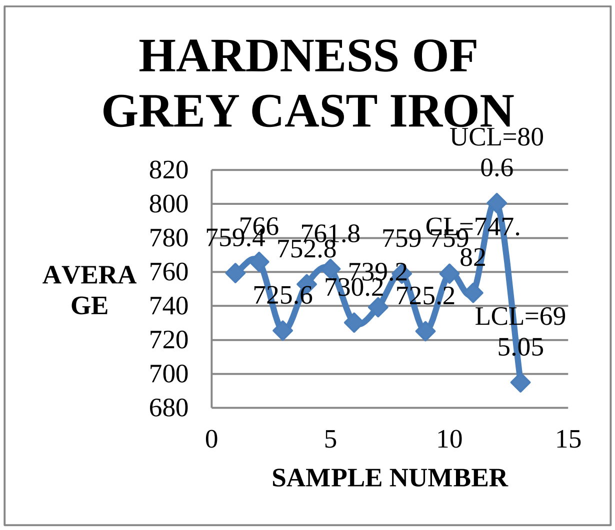

Figure 7.0 X chart: Control chart for average of hardness of grey cast iron

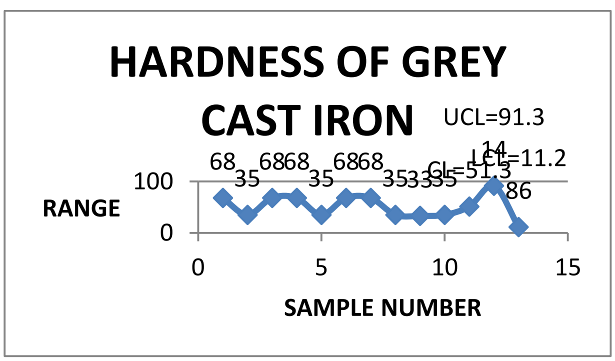

Figure 8.0 R chart: Control chart for range of hardness of grey cast iron

7.0RESULTS AND DISCUSSIONS

7.1 INTERPRETING CONTROL CHARTS FOR VARIABLES

We can see the behaviour of the figures where 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 vairabilty in the prodcution process , this was achieved by using a control chart 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 R chart , a control chart was used , in which the ranges were plotted. The 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 $D_{3(0.22)}$ and $D_{4(\ 1.78)}$ given in Table (Factors A_2, D_3 and D_4 for X and R chart for three- standard –devaition control limits), Source: Everette.Adam, Jr Ronald J. Ebert ,Production and operations Management –concepts ,Models ,and Behavior,5th ed.(Prentice –Hall of India private limited New Delhi -110001 2003), p.640. 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 the three elements and the hardness values of grey cast iron were all within the standard range . The process should therefore be allowed to continued and more effort is required to sustain the trend and the behaviour of the production process.

8.0 CONCLUSION

We can conclude by saying that the use of statistical quality control process had helped the shop to control the production process in which both the chemical compositions and hardness values are all within the process control. Indicating that all the points are within the Upper Control Limit and Lower Control Limit.

The process further assisted in monitoring and eliminating bad products,rejects scraps and thus reduced wastes that could have had caused problems on the production of grey cast irons.

The quality of the products and the production processes were confirmed ,which indicated how the products will meet the requirment, specifications and satisfaction of the customer

The process indicated that the cast 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 extend agreed and conformed with International Standard Organization (ISO) and that of Standard Organization of Nigeria (SON).

Finally, the use of the statistical quailty control had assisted in detecting and eliminating non-random (Sporadic) variation in the production process and had also determined that the chemical compositions and hardness values of grey cast iron products could be produced with zero defect , which mean that the products are defect free through prevention .

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