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Quality Control of Defective Rotary Shouldered Connections Using Statistical Quality Control: A Case Study

Amadi Rex Kemkom Chima[1], Wali Stanley Aleruchi[2], Orokor Allwell Chiyonu[3]

'Department of Mechanical Engineering, Rivers State University, Port Harcourt, Nigeria'

E mail: Amadikemkom@gmail.com

ABSTRACT

This work was aimed at carrying out quality control on defective rotary shouldered connections using statistical quality control at a manufacturing company in Port Harcourt, Nigeria. In order to achieve the aim, the fractional defective of the manufactured product was ascertained, the point of maximum defect using p chart was ascertained as well as the various causes of the defects using fishbone diagram. The results of the P chart showed that the fractional defective was 0.39508, 0.30363, and 0.26877 for years 2018, 2019, and 2020 respectively. The causes of the defects included use of inherently bad materials, incorrect stock dimension, work piece vibration, and poor operator skill. It was recommended that materials should be inspected on arrival to identify signs of deterioration using liquid penetrant test and non-destructive test, carry out in-process inspection to ensure that the process is under control at every machining stage, use correct tools, feed and speeds, and to strictly follow product drawings and machining processes sheet for quality assurance.

KEYWORDS: ***Statistical Quality Control, Rotary Shouldered Connections, Defects***

1. INTRODUCTION

Lilly *et al.* (2015) opined that the purpose of manufacturing companies is to construct and sell artefacts products to satisfy an existing or created demand, thereby to make profit; achieve a high return on investment, provide employment in the community by supplying commodities needed by society. These targets are frequently of secondary importance, the main being to perpetuate the business. To achieve this purpose, it is important to maintain high quality of products or services as it shows satisfaction derived.

Yonatan *et al.* (2013) opined that a happy customer is more preferable to a loyal customer, this is because a happy customer is one who is satisfied while a loyal customer is one who regardless of the service gotten still returns for more service. The existence of many companies on the market is conditioned with a number of satisfied customers. Customers are key factor of the existence and company development on the market. Customer satisfaction is often associated with the customer gratification. Products or service that are source of satisfaction provide the desirable value to their customers, at least in a sufficient degree. According to Grzegorz & Jolanta (2011), satisfaction is a judgment, an opinion expressed by the customer. The degree is a judgment, an opinion expressed by the customer. The degree of satisfaction reflects the gap between the customers vision of the expected products and customer perception of the delivered product (Grzegorz & Jolanta, 2011).

Hairulliza *et al.* (2014) opined that quality can be defined as fulfilling specification or customer requirement without any defect, as such a product is said to be in high quality if it is functioning as expected and reliable. According to Annisa (2019), ISO 8402-1986 defines Quality as the totality of features and characteristics of a product or service that bears the ability to satisfy the ability to satisfy stated or implemented need. As such Quality is a measure of excellence or a state of being free from defects and variations to achieve uniformly in order to keep the loyalties of customers and maintain customer satisfaction. Yonatan *et al.* (2013) further opined that improvement in quality of product is pertinent for a company in order to survive and to grow in competitive market. Quality plays an important role for a company to become more efficient and effective in the global market, Hence, quality helps improve the productivity, customer loyalty along with the market share.

Laurent and Hermel (2004) in Latif (2016) opined that there is a linkage between quality and profit. It is considered a competition source of the organization leading to customer satisfaction, increasing loyalty, elevating the organization profit on short and long term. This implies that quality leads to satisfaction, while satisfaction, while satisfaction leads to loyalty and loyalty leads to profit.

According to Latif (2016) satisfaction is the impression of reward received by the customer after making the sacrifice of purchasing a product. As such, satisfaction is a positive impression from the customer side towards the consumed product, this impression is found by comparing the customer expectation with the actual product performance. Latif (2016) further described satisfaction as a psychological state following the purchase of a product translated by a temporary feeling resulting from the difference between the customer expectations and the actual realization, being parallel with the previous time with the service.

According to Murco and Sanin (2018) defects are drop in manufacturing quality. These defects may occur before processing, during processing, and after processing.

This work seeks to eliminate these defects to as low as reasonably practicable using statistical quality control. According to Mislan (2020) quality control is a technical and management activity that measures quality characteristic of a product or a service, then compare the measured result with product specification and taking the improvement action appropriately if there is a difference among the product standard. It was further stated that statistical quality control (SQC) offers the tools for solving the problem such as process stability, identify opportunities to improve, and decreasing the variability.

Yash and Vikram (2020) studied variability in a manufacturing process causes defects in the final products which in turn hampers quality, productivity, profitability, and ultimately, the customer satisfaction, with the main objective of minimizing the defect rates and variability in the final product by using Statistical Process Control (SPC) tools in a biscuit production unit thereby increasing its productivity, profitability and competitive advantage in the market. Several problems in production have been scrutinized by using SPC tools like Pareto analysis, Cause-and-effect diagrams, attribute control charts (p-charts) and process capability analysis. Several types of defects were considered namely biscuit defects and packaging defects. On executing the Pareto analysis, three most contributing types of defects were found which when summed up constituted approximately 82% of the total defects. These defects are Breakage (41%), Blisters (26%) and Off registration (15%). For the above-mentioned defects, cause-and-effect diagrams were constructed to pin point towards the possible root causes of those problems. On the basis of these root causes, certain improvements were recommended. Attribute control charts were plotted and process capability analysis was carried out for data of proportion of defect collected before and after the improvement recommendations were implemented. It was found that the process of production went from being erratically out of control to being well within the control limits after the improvement recommendations were implemented.

Gijoa *et al.* (2011) applied Six Sigma methodology in reducing defects in a fine grinding process of an automotive company in India. The DMAIC (Define–Measure–Analyse–Improve–Control) approach has been followed here to solve the underlying problem of reducing process variation and improving the process yield. It explored how a manufacturing process can use a systematic methodology to move towards world-class quality level. The application of the Six Sigma methodology resulted in reduction of defects in the fine grinding process from 16.6 to 1.19%. The DMAIC methodology had a significant financial impact on the profitability of the company in terms of reduction in scrap cost, man-hour saving on rework and increased output.

Warinah (2019) carried out a study is to reduce the number of defects in the assembly process of PT. XYZ using the Six Sigma (DMAIC) methodology. The results showed that there were 5 dominant types of defects related to Critical to Quality (CTQ), namely Undercement, Dirty shoes, Unpairing-heel height, Broken stitching and Quarter wrinkles. Furthermore, an analysis of the causes of defects was carried out by using cause and effect diagrams and an improvement effort using 5W + H analysis. The results of efforts to decrease the number of defects in the assembly process using the DMAIC method show that the DPMO value for these five CTQ defects decreased to 2056 PPM from 3898 PPM or decreased by 47.3%. Whereas for the value of the sigma level obtained 4.39 σ from 4.16 σ.

Mislan (2020) carried out quality control of steel deformed bar product using statistical quality control (SQC) and Failure Mode and Effect Analysis (FMEA). The Percentage of steel deformed bar product defect in an Indonesian factory was 0.064% by 2019, where the defect percentage exceeded a limit target set by the company, which is 0.050%. Statistical Quality Control (SQC) method was utilized by applying the Seven Tools to identify the problems that caused defects in the product. Failure Mode and Effect Analysis (FMEA) was applied into the production process to generate solutions for the cause of dominant defect factors. According to the calculated RPN value, the cross defect was caused the most by uncentered between top roll and bottom roll. For scratch defect, the main factor carried by Spindle Carrier that is vibrating during the rolling process. The line defect caused by a worn caliber. By implementing the recommended solution, the percentage of product defects decreased from 0.064% to 0.0075% during March to June 2020.

2. MATERIALS AND METHODS

2.1 Materials

The material used in this work is the rotary shouldered connection which is an API, SPEC 7-1 pipe connection used in the Transportation of Oil and Gas. The rotary shouldered connection is pictured in Figure 1.

Figure 1: The Rotary Shouldered Connection

The data used in this work was obtained from a manufacturing company which is a local content company founded in 2002 based in Port Harcourt. The data includes unit produced and defective units. The rotary shouldered connection is pictured in Figure 1.

2.2 Analytical Models

Models for the analysis of data obtained from defects of the rotary shouldered connections is discussed in subsections 2.2.1. The optimization tool used for the analysis of the defective product is MATLAB software.

2.2.1 Control Charts

To determine whether or not the manufacturing process of the round-shouldered connections is under control P-chart is utilized, MATLAB is used as the optimization tool. According to Lilly *et al.* (2015), the steps for setting up the P-chart are:

i. Record the data of the number of items inspected as well as the defectives observed,
ii. Determine the fraction defective,
iii. Compute the Upper and Lower Control Limits,
iv. Plot a graph of fraction defective against sample item,
v. Identify the points that are outside the upper and lower control limits.

The models to be used for the statistical quality control analysis in P-chart for the rotary shouldered connections machining processes in the machine shop on this research are show as follows;

To determine the fraction defective of the product, Equations (1) was utilized as stated by Lilly *et al.* (2015).

$$F = \frac{\sum u}{N} \tag{1}$$

where

P = Fraction defective

u = Number of defective units

N = Total number of inspected items

Furthermore, the standard deviation of the process as opined by Mikell (2012) is given as

$$\sigma = \sqrt{\frac{F(1-F)}{n}} \tag{2}$$

where

F = Fraction defective

n = Number of defective

To determine the UCL and LCL, Equations (3) and (4) is utilized as given by Lilly *et al.* (2015).

$$\text{UCL}_p = p + 3\sigma \tag{3}$$

$$\text{LCL}_p = p + 3\sigma \tag{4}$$

where

p = Mean value

σ = Standard deviation

n = Total number of inspected

$\sum P$ = Total number of defectives

3. RESULTS

2.1 Statistical Quality Control Results for 2018

The result obtained from the control chart analysis carried out on the defects on the rotary shouldered connection during machining from quality control records of the Manufacturing Company are shown in Table 1.

Table 1: Statistical Quality Control Analysis of the Rotary Shouldered Connections for 2018

Unit Produced	Defectives	Fraction Defective (P)	Upper Control Limit (UCL)	Lower Control Limit (LCL)
25	4	0.16	0.37996	-0.059964 -
27	6	0.22222	0.46225	0.017805
32	12	0.375	0.63174	0.11826
22	7	0.31818	0.61609	0.020274 -
31	6	0.19355	0.40642	0.019326 -
20	4	0.2	0.46833	0.068328
45	19	0.42222	0.64311	0.20134
38	8	0.21053	0.40893	0.012122
41	13	0.31707	0.53509	0.099053
30	11	0.36667	0.63061	0.10272
14	6	0.42857	0.82535	0.031791
29	12	0.41379	0.68816	0.13942
354	**108**	**0.30508**	**0.3785**	**0.23167**

From Equation (1), the fraction defective is calculated as:

$$F = \frac{108}{354}$$

$$F = 0.30508$$

The standard deviation as calculated using Equation (2) is;

$$\sigma = \sqrt{\frac{\mathbf{0.30508}(1-\mathbf{0.30508})}{354}}$$

$$\sigma = 0.024472$$

The upper control limit as determined by Equation (3) is

$UCL_P = 0.30508 + 3(0.024472)$

$UCL_P = 0.3785$

Furthermore, the lower control limit as determined by Equation (4) is

$LCL_P = 0.30508 - 3(0.024472)$

$LCL_P = 0.23167$

Fraction Defective

Unit Produced

Figure 2: P-Chart of the Rotary Shouldered Connections for 2018

From Figure 2, out of 12 data points, it is observed that 8 falls outside the control limits, this implies that the result did not display statistical control. This was due to defects that were inherent in the rotary shouldered connections which were discovered during final inspection using Liquid penetrant test and Non-destructive test.

2.2 Statistical Quality Control Results for 2019

The result obtained from the control chart analysis carried out on the defects on the rotary shouldered connections during machining from quality control records of the Manufacturing Company are shown in Table 2.

Table 2: Statistical Quality Control Analysis of the Rotary Shouldered Connections for 2019

Unit Produced	Defectives	Fraction Defective (P)	Upp2er Control Limit (UCL)	Lower Control (LCL)
13	6	0.46154	0.87633	0.046746
17	10	0.58824	0.94633	0.23014 -
25	4	0.16	0.37996	0.059964
20	11	0.55	0.88373	0.21627 -
26	4	0.15385	0.36612	0.058431
22	10	0.45455	0.77302	0.13607 -
19	5	0.26316	0.56623	0.03991
26	10	0.38462	0.67085	0.098381
24	7	0.29167	0.57001	0.013325
33	5	0.15152	0.33876	-0.035732
41	11	0.26829	0.47588	0.060705
37	9	0.24324	0.45484	0.031642
303	**92**	**0.30363**	**0.38288**	**0.22438**

From Equation (1), the fraction defective is calculated as:

$$F = \frac{92}{303}$$

$$F = 0.30363$$

The standard deviation as calculated using Equation (2) is;

$$\Sigma = \sqrt{\frac{\mathbf{0.30363}(1-\mathbf{0.30363})}{303}}$$

$$\sigma = 0.026416$$

The upper control limit as determined by Equation (3) is

$$\mathrm{UCL}_P = 0.30363 + 3(0.30363)$$

$$\mathrm{UCL}_P = 0.38288$$

Furthermore, the lower control limit as determined by Equation (4) is

$$\mathrm{LCL}_P = 0.30363 - 3(0.026416)$$

$$\mathrm{LCL}_P = 0.22438$$

Fraction Defective

Unit Produced
Units Produced

Figure 3: P-chart of the Rotary shouldered connections for 2019

From Figure 3, out of 12 data points, it is observed that 7 falls outside the control limits, this implies that the result did not display statistical control. This was due to defects that were inherent in the rotary shouldered connections which were discovered during final inspection using Liquid penetrant test and Non-destructive test.

2.3 Statistical Quality Control Results for 2020

The result obtained from the control chart analysis carried out on the defects on the rotary shouldered connections during machining from quality control records of the Manufacturing company are shown in Table 3.

Table 3: Statistical Quality Control Analysis of the Rotary Shouldered Connections for 2020

Unit Produced	Defectives	Fraction Defective (P)	Upper Control Limit (UCL)	Lower Control Limit (LCL)
17	7	0.41176	0.76986	0.053671 -
19	5	0.26316	0.56623	0.03991
33	5	0.15152	0.33876	0.035732

26	8	0.30769	0.57924	0.036147
37	11	0.2973	0.52272	0.071873 -
23	4	0.17391	0.41102	0.06319
31	13	0.41935	0.68524	0.15347
25	7	0.28	0.5494	0.010601
42	8	0.19048	0.37225	0.0087022
253	**68**	**0.26877**	**0.37245**	**0.22279**

From Equation (1), the fraction defective is calculated as:

$$F = \frac{68}{253}$$

$$F = 0.26877$$

The standard deviation as calculated using Equation (2) is;

$$\sigma = \sqrt{\frac{\mathbf{0.26877}(1-\mathbf{0.26877})}{253}}$$

$$\sigma = 0.024943$$

The upper control limit as determined by Equation (3) is

$$\mathrm{UCL}_P = 0.26877 + 3(0.024943)$$

$$\mathrm{UCL}_P = 0.37245$$

Furthermore, the lower control limit as determined by Equation (4) is

$$\mathrm{LCL}_P = 0.26877 - 3(0.024943)$$

$$\mathrm{LCL}_P = 0.22279$$

Fraction Defective

Unit Produced

Figure 4: P-chart of the Rotary Shouldered Connections for 2020

From Figure 4, out of 9 data points, it is observed that 5 falls outside the control limits, this implies that the result did not display statistical control. This was due to defects that were inherent in the rotary shouldered connections which were discovered during final inspection using Liquid penetrant test and Non-destructive test.

4.4 Fishbone Diagram

The variables identified during brainstorming are summarized using the fishbone diagram. The diagram visually outlines which variables affects which phase of the process. In determining the possible causes, several main factors like materials, operator, measurements, and machine were considered as shown in Figure 5.

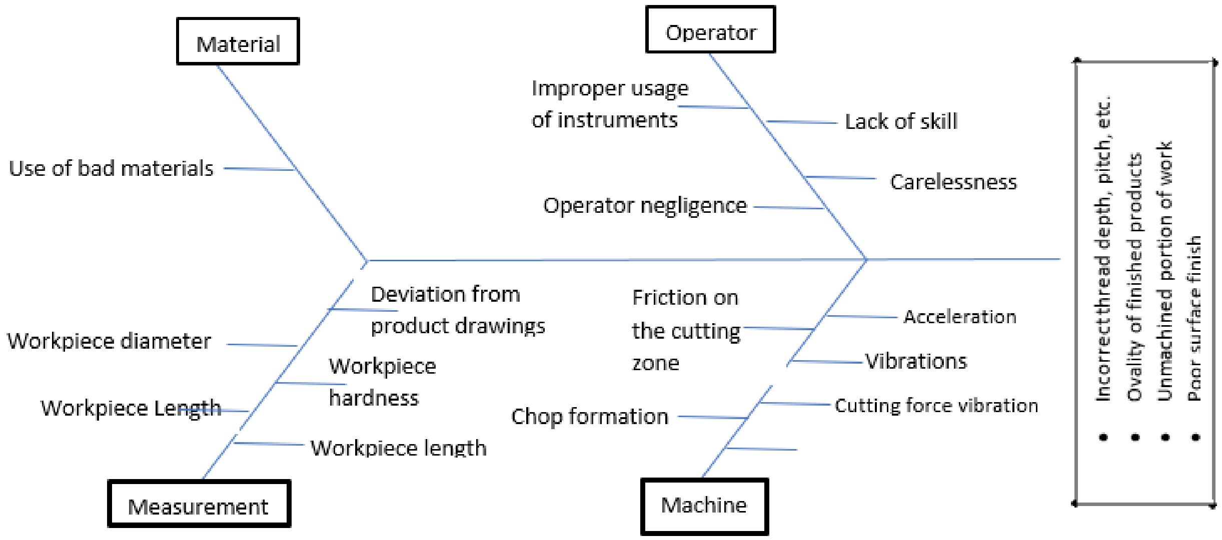

Figure 5: Fishbone Diagram of the Rotary Shouldered Connection

4. CONCLUSION

From the statistical quality control analysis of results using p-chart carried out on the defects of the rotary shouldered connections in the machine shop within a period of five years, the following conclusions were drawn.

i. That machining process was out of statistical control due to the high extent of nonconformance of the rotary shouldered connections to customer specifications and standard requirement with fraction defective of 0,30508, 0.30363, and 0.26877 for years 2018, 2019, and 2020 respectively.
ii. That results of statistical analysis of product data carried out show that more sample values are above the UCL and below LCL respectively (8 in 2018, 7 in 2019, and 5 in 2020) which is abnormal and shows that the production process was not properly controlled.

Furthermore, from the Fishbone diagram, the following conclusion were drawn;

i. Unskilled personnel errors such as lack of skill, operator negligence, improper usage of instruments, and carelessness led to poor quality of products produced like ovality of the product
ii. Also friction on the cutting zone, chip formation, acceleration, and vibration, caused breakdowns of machines thereby leading to long manufacturing process
iii. Use of incorrect stock dimension and inherently bad material led to defects of the manufactured products
iv. That condition of materials used for rotary shouldered connections were not inspected at the incoming stage until the final inspection before spotlighting the causes of the product defects.

From the detailed analysis, the following recommendations were made

i. Materials should be inspected on arrival to identify signs of deterioration. Before machining, tests such as liquid penetrant test and non-destructive test should be carried out on products to ascertain whether there are hidden cracks which will grow and make the end product fail.
ii. Carrying out in-process inspection is a better-quality control measure to ensure that the process is under control at every machining stage.
iii. Also, analysis of both conforming and nonconforming products should be carried out and plotted in the P-chart which is constructed and studied to know that the process was under statistical control or not based on the control limits,
iv. Strictly follow product drawings and machining processes sheet for quality assurance and realization of product quality as per specified control limits. With the implementation of these

correction and corrective actions on subsequent rework and production processes are in line with ISO 9001 etc. a better quality is sure,

v. Adequate training and retraining of personnel to be more careful,

vi. Use correct tools, feed and speeds.

vii. Adopt preventive maintenance on machines and equipment.

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