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A Statistical Process Control Technique for Reducing Product Non-Conformities: A Case Study of Production of Crossover

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ABSTRACT:

The aim of this paper is to use statistical process control technique to reduce non-conformance in the production process of crossovers. In the machine shop of the case study company, there has been issues of large number of non-conforming crossovers after carrying out magnetic particle tests at the final inspection stage. This resulted in waste of resources associated with increased scrap production, reworking of non-conforming product and waste of time. As a way of improving quality of crossovers produced, this research adopted the use of P-Chart which is a Statistical Process Control technique for analysing inconsistencies with machined crossovers through a period of 5years. Results from the five consecutive years (2014 - 2018) show that 7 points out of 12 points fell out of control limits in 2014, 9 points out of 13 points fell out of control limits in 2015, 6 points out of 11 points fell out of the control limits in 2016, 7 points out of 14 points fell out of the control limits in 2017 and 4 points out of 14 points fell out of the control limits in 2018. These results show that the process was a faulty one and there was need to improve on it in order to reduce the number of non-conformities to the barest minimum. This study reveals that materials from the supplier needed to be inspected to ensure there were no hidden flaws (cracks). This is capable of reducing defective products thereby making the crossovers conform to customer specification.

KEYWORDS: Crossover, Non-conformities, Quality, Statistical Process Control, p-chart

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1. INTRODUCTION:

It will be agreed that at one occasion or another, it has been experienced that a product purchased was later discovered to be defective or that some components where missing while assembling it. Feedbacks of this manner from end-users has become a challenge to the producers of products that warrants designing ways to monitor the quality of products produced and eliminate potential causes of defect and equally build quality in the production process.

The ultimate aim of any manufacturing company is the production of quality goods and services for the satisfaction of consumers and to maximize profit. The quality of product may be checked for defectives utilizing the statistical quality control technique, which is either statistical process control or acceptance sampling methods (Kaynak, 2003).

This study considers controlling the deviation of finished Crossover from the customer specifications. Crossovers are threaded pipes of varying diameter which are used for producing and transporting oil and gas from reservoir to storage facilities. The commitment to quality and to improvement of production processes in the machine shop of a manufacturing firm is the motivation for this study.

Study of the production company showed that it was faced with challenges of regular emergency call for reworking of non-conforming products, recording more scraps from defective products, threat of withdrawal of their API Spec Q1 operational license. Also, the observed process non-conformance to API Spec Q1 9th Edition/ISO requirements have led to frequent outsourcing of jobs to third parties, which is far more expensive compared to when internally executed, damaged reputation and lost market share. Just as Taguchi (2007) opined, it is the sole responsibility of manufacturers to improve quality as the losses bounce back to them.

Challenges such as waste of material and time loss during the reworking or reproduction of rejected finished products are prevalent problems in the manufacturing sector, which prompts the need to study the production process and proffer solutions.

Quality is the characteristic a product possesses that speaks volumes of it (Mikell, 2010). Quality is the goodness of products or services (Heizer & Render, 2011). It is the conformance to specification and the degree at which specifications reflect on customers' true need and desire in order to compete in the internal market (Gaspersz, 2007; Gaspersz, 2012).

Studies show that whenever products are manufactured, it is observed that no two units of the products are similar because there occur some variations in the process due to inherent traits of the process (Khurmi & Gupta, 2009). Indices such as length, diameter, thickness, hardness, height, temperature, color, etc., which are used for measuring or gauging whether a product has quality are termed quality characteristics (Khurmi & Gupta, 2009). It was further stated that, quality characteristics of a product which are inspected by actual measurement are known as variables, whereas quality characteristics of a product which are not measured directly but gauged to determine whether they may be accepted or rejected are called attributes. Variations due to chance caused which depend on machine tool, are not considered in quality control since the variations are usually minute and follow a normal distribution. However, assignable causes are due to tool wear, tool setting and loosed tool (Khurmi & Gupta, 2009).

According to Lilly et al. (2015), quality control is the maintenance of specified quality standards which can accommodate the inherent variability in a product. Furthermore, it was made clear that every production process is prone to variability, which may be chance caused or assignable to a cause. The process is under statistical control when variation is due to chance cause, and out of statistical control when variation is due to assignable cause.

According to Murray and Larry (2011), the variation in any process is mainly due to common causes or special causes. It was further explained that common causes of variation are those natural variations that exist in materials, while the special causes (also known as assignable causes) of variation are those that arise due to excessive tool wear, change in material, new supplier and a new operator who may be inexperienced or careless with material handling. Furthermore, it was pointed that a process needed to be under control for easy predictability. They further explained that products not meeting specification are called non-conforming products, while the non-conforming products that are not reparable or usable are called defective products. This implies that defective products are worst case scenario of non-conforming products.

Quality costs can be minimized by improving the production processes through effective use of statistical quality control technique. According to Raghuwanshi (2011), statistical quality control is classified into attribute methods which indicate the presence or absence of quality characteristics such as color, surface finish, etc., in a product inspected for acceptance or rejection; and the variable method which depends on using measurable data such as length, diameter, thickness and weight, as basis for acceptance or rejection.
Statistical Quality Control techniques for improving quality are descriptive statistics, acceptance sampling and Statistical Process Control (Mahajan, 2009). Statistical Process Control uses control charts and sets control limits. It ascertains capability of a manufacturing process as well as why a capable process is failing to meet specification.

Control charts were defined as graphical techniques in which statistics computed from measured values of certain process characteristics are plotted over time to determine if the process is under statistical control. The aim of statistical process control is to ensure that a given manufacturing process is as stable (in control) as possible and that the process operates within stated values for the product with as little variability as possible. It also aims at reducing variability to ensure that each product is of as high quality. When a control chart which is used, a process is said to be out of control when a plot of data reveals that one or more data points fall outside the control limits. The chart is comprised of three horizontal lines which include the center, the upper control limit (UCL) and lower control limit (LCL), such that the upper and lower control limits are ± 3 standard deviation from the sample mean as shown in Figure1. The vertical axis is expressed in decimal fraction, while the horizontal axis expresses the number of samples produced.

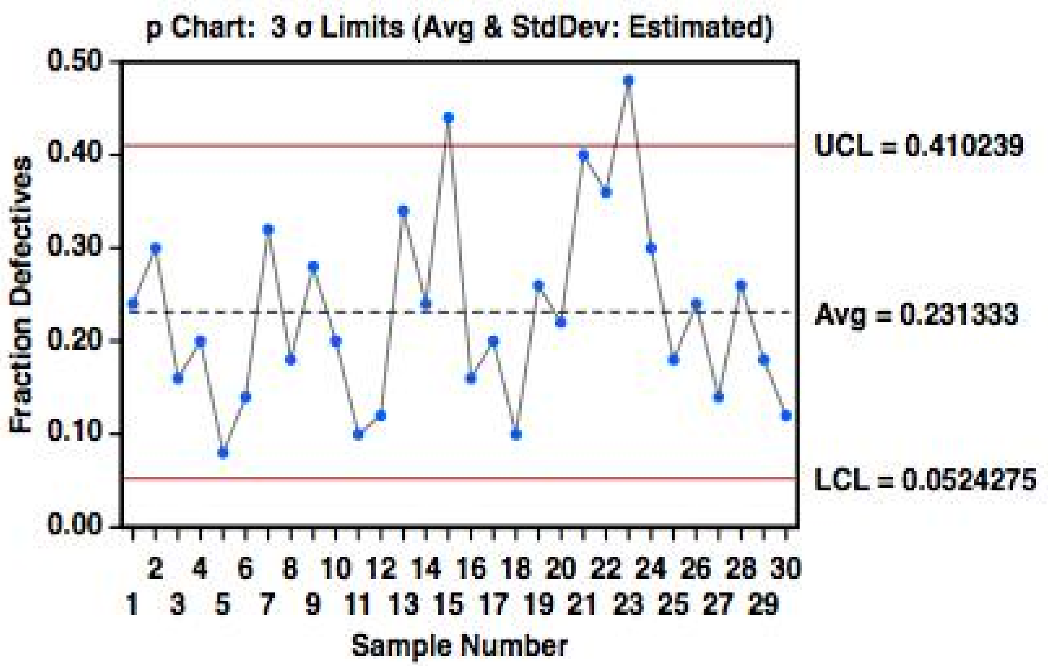

Fig 1: A sample of control chart (Gigawiz, 2016)

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This work adopted the statistical process control techniques on the quality records of the machining process of crossovers. A crossover is a one-piece tubular section used for the purpose of joining or changing from one size, weight, or type of thread connection to the same or another size, weight, or type of thread connection. Figure 2 shows a picture of a cross over.

Fig 2 A Picture of a Crossover Oil Tool.

2. MATERIALS AND METHODS:

The method for reducing product defects can be realized when consideration is given to the manufacturing processes followed, choice of material selected and the stages of inspection carried out. The methods utilized in this study include identification of the company's production process as shown in Figure 3, modified production process as shown in Figure 4, modelling of a more efficient production process as shown in Figure 5, construction of P-chart as shown in Figure 6 and Figure 7. This would double check the inspection of received raw materials by way of mitigating product rejection due to inherent defects in the material chosen for production.

Fig 3 Manufacturing Process in the Company's Machine Shop.

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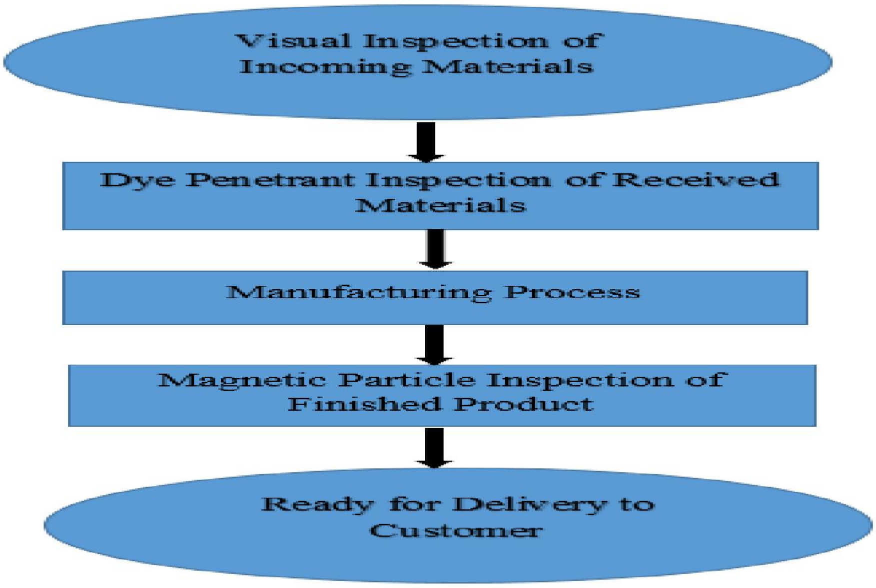

Fig 4 Modified Manufacturing Process

Analytical Models:

Models for the analysis of data obtained from nonconforming crossovers from 2014 to 2018 is discussed here. The optimization tool used for the analysis of data is MATLAB software.

2.2 Statistical Process Control:

The models to be used for the statistical process control analysis of the crossover machining processes are discussed as follows:

$$\bar{p} = \frac{\sum_{i=1}^{m} P_i}{n} \qquad (1)$$

(Mikell, 2010)

$$\sigma = \sqrt{\frac{\bar{p}(1-\bar{p})}{n}} \qquad (2)$$

(Lilly et al, 2015)

$$UCL_{\bar{p}} = \bar{p} + 3\sigma \qquad (3)$$

(Lilly, 2015)

$$LCL_{\bar{p}} = \bar{p} - 3\sigma \qquad (4)$$

(Lilly, 2015)

where

σ = Standard Deviation

$\bar{p}$ = mean value

n= total number of samples inspected.

$\sum_{i=1}^{m} p_i$ = Total number of defectives

p_i = fraction defectives

i = identified sample

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2.3 Process Evaluation Model:

Process evaluation that would enable any organization to know if a production (machining) process is under control or not is modeled as shown in

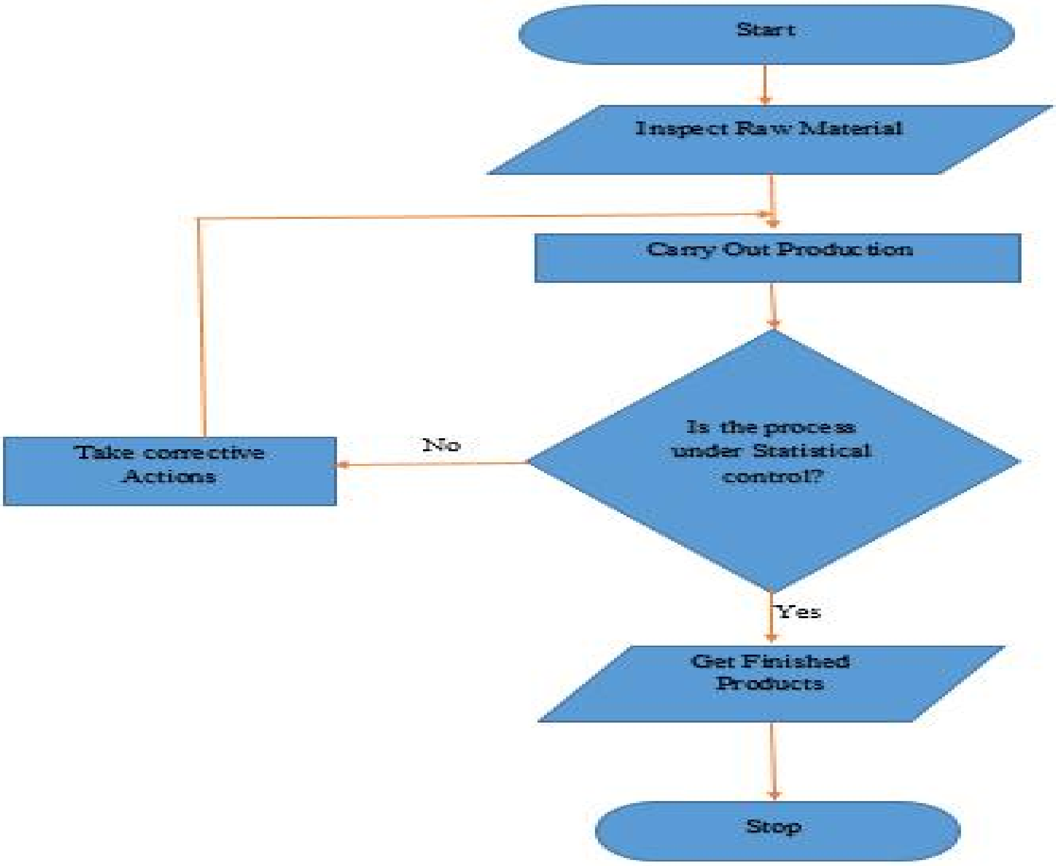

Fig. 5 Flow diagram of Production Process Evaluation

3. RESULTS AND DISCUSSION:

Results obtained from statistical process control analysis carried out on the threading, rechasing, boring operations of crossovers based on quality records from the machining process sheet of the machine shop between 2014 and 2018 are shown here.

3.1 SPC Analysis of Crossovers' Machining Process in 2014

Applying equation (1) while substituting data obtained from quality records of machined crossovers, the mean or central control is estimated thus:

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$$\bar{p} = \frac{110}{263}$$

= 0.418251

Standard deviation is estimated from equation (2) as

$$\sigma = \sqrt{\frac{0.418251(1 - 0.418251)}{263}}$$

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Hence, the upper control limited based on equation (3) is

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$$= \mathbf{0.509500}$$

Then from equation (4)

$$LCL_{\bar{p}} = 0.418251 - 3(0.030416)$$

$$= \mathbf{0.327003}$$

Results obtained from the statistical process control (SPC) analysis in 2014 are shown in Tables 1. The raw data used for SPC analysis were obtained from the company's quality record of 2014.

Table 1: Result of SPC Analysis in 2014.

UNITS PRODUCED	DEFECTIVES	P	UCL	LCL
8	5	0.625	1.138489898	0.1115101
10	6	0.6	1.064758002	0.135242
13	4	0.307692308	0.69171552	-0.0763309
15	10	0.666666667	1.031815038	0.30151829
18	5	0.277777778	0.594493174	-0.0389376
21	9	0.428571429	0.752540977	0.10460188
24	10	0.416666667	0.718570349	0.11476298
25	9	0.36	0.648	0.072
28	8	0.285714286	0.541834702	0.02959387
30	14	0.466666667	0.739918687	0.19341465
31	19	0.612903226	0.87535296	0.35045349
40	11	0.275	0.486800319	0.06319968
263	**110**	**0.418250951**	**0.509500282**	**0.32700162**

The results in Table 1 show that from January to December in 2014, a total of 263 crossovers were manufactured. 110 were found defective after running SPC analysis using MATLAB software. Also, the mean value (0.418251), upper control limit (0.509500) and lower control limit (0.327003) were determined using equations (1), (2) and (3).

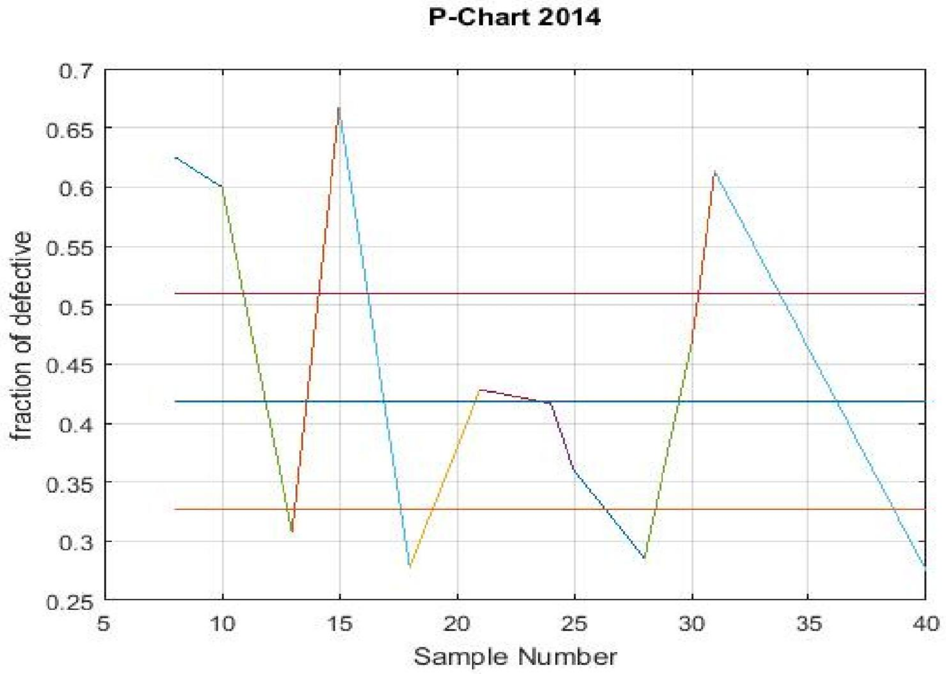

Fig 6 A P-Control Chart of Crossovers in 2014.

In Figure 6, 7 points out of 12 points fell outside the control limits (0.509500, 0.327003) which is a reason to accept that the process did not exhibit statistical control. Basically, these were due to defects inherent in product material which were detected during final inspection using the nondestructive tests such penetrant test and magnetic particle test.

3.2 SPC Analysis of Crossovers' Machining Process in 2018:

Applying equation (1) while substituting data obtained from quality records of machined crossovers, the mean or central control is estimated thus:

$$\bar{p} = \frac{154}{476}$$

Error! Reference source not found.**0.323529**

Standard deviation is estimated from equation (2)

$$\sigma = \sqrt{\frac{0.323529(1-0.323529)}{476}}$$

$=$ 0.021442

However, the upper control limited based on equation (3) is

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Hence, from equation (4)

$$LCL_{\bar{p}} = 0.323529 - 3(0.021442) \quad = \mathbf{0.259202}$$

Results of statistical process control (SPC) analysis of data obtained from the company's quality record in 2018 are shown in Table 2.

Table 2: Result of SPC Analysis of Cross Overs' Machining Process in 2018.

UNITS PRODUCED	DEFECTIVE UNITS	P	LCL	UCL
27	9	0.333333	0.061168	0.605499
30	11	0.366667	0.102722	0.630611
40	13	0.325	0.10283	0.54717
31	12	0.387097	0.124647	0.649547
29	12	0.413793	0.139421	0.688165
38	10	0.263158	0.048857	0.477459
25	4	0.16	-0.05996	0.379964
45	11	0.244444	0.052251	0.436638
22	7	0.318182	0.020274	0.61609
31	9	0.290323	0.045748	0.534897
44	17	0.386364	0.166148	0.606579
60	19	0.316667	0.136505	0.496829
14	6	0.428571	0.031791	0.825351
21	9	0.428571	0.104602	0.752541
19	5	0.263158	-0.03991	0.566226
476	**154**	**0.323529**	**0.259202**	**0.387857**

The results in Table 2 show that from January to December in 2018, a total of 476 crossovers were manufactured. 154 crossovers were found defective after running SPC analysis using MATLAB software. Also, the mean value (0.323529), upper control limit (0.387857) and lower control limit (0.259202) were determined using equations (1), (2) and (3).

4. CONCLUSION

Statistical process control analysis using the P-chart was carried out on crossovers in the machine shop within a period of five years and results obtained have led to reaching the following conclusions:

(i) That condition of materials used for crossovers were not inspected at the incoming stage until the final inspection

(ii) That results of statistical analysis of product data carried out show that more data points fell outside UCL and LCL respectively.

(iii) That the machining process was out of statistical control due to the high extent of non-conformance of the crossovers to customer specifications and standard requirements (API, 2014).

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