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Detecting Production Line Defect Using Control Chart

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Abstract: The process of quality control in production line is vital for manufacturers in order to sustain mass production product with low cost and high quality. Therefore, the purpose of this study is to develop a statistical control chart for defect detection of microprocessor production line. This study is to observe the pattern of process variability based on 40 lots of product's samples from the production lines. There are three defect identification methods used in this study, i.e., special top plates, Tim and Adhesive line and control charts. The data is analyzed by using minitab16 statistical software. The finding shows that the control chart is able to identify the control limits of sample defects. Hence, manufacturers are able to make decision either to correct or reject the defective products. It also allowed the manufacturers to revise the center line and control limits for changes in production. However, further study is needed, especially on the use of the control chart for the purpose of problems identification, correction and permanently preventing it from recurring.

Key words: Quality control, control chart, top plate, Tim and Adhesive line, production line

INTRODUCTION

Quality control is crucial for most companies to build a successful business that produces products or services that meet or exceed customer's expectations. It is also as a basis for company efficiency, minimizes waste and produces a high level of productivity. It enables products to compete in global market, act as a company reputation and to comply the clients or legislation standard. There are many ways for companies to control their quality such as by recognizing for a quality standard accreditation such as ISO 9001 which is published by the international organization for standardization.

The basic tools of quality are called the seven basic tools of quality that can be used to solve the majority of quality-related issues. They are "fishbone" or Ishikawa diagram; check sheet; control chart; histogram; pareto chart; scatter diagram and stratification. In this study, the Control Chart (CC) is used, since it is a popular method and has been widely used by manufacturers in processing abnormality detection. It is a graph used to study the change of process over the time and the data is plotted in time order. A CC has a central line for the average, an upper line for the upper control limit and a lower line for the lower control limit. These lines are determined from historical data by comparing current data to these lines. As a conclusion, CC can be used to identify whether the process variation is in control or is out of control, affected by special causes of variation.

CC has been used in numerous fields because it can produce a comprehensive graphical display that users can easily configure (Chen *et al*., 2015). Such as monitoring a service quality, condition of patients and network traffic behavior (Yu, 2012); analyzing in large data sample as an efficient optimal solutions monitoring manufacturing process and Kang and Kim use it in reducing false alarms.

CC is also used to compare between variables control charting and other inspection for various scenarios in economics (Tannock, 1997). Meanwhile, Simionescu (2015) developed it to predict the national unemployment rate by using unemployment rates at regional level. Gilenson *et al*. (2015) formulated a trade-off between the expected values of the CT and the die yield and found out that the control chart model enables decision makers to knowingly sacrifice Yield to shorten CT and vice versa.

This study employed the CC in order to identify defect on production line. As Goetsch and Davis found, CC is able to separate variation resulting from special causes of natural variation and to establish and maintain consistency in process as well as enabling process improvement. They added that CC application also able to reduce variability of the key quality characteristic, achieving process stability and improving productivity as well as able to detect defect sample and identify abnormal conditions so as to prevent defects, scrap and rework of final products.

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Even though CC is a popular tool by many researchers and practitioners but there are some limitations of CC such as the inability to take into account the relationships between the quality characteristics in multivariate processes which are frequently encountered in modern manufacturing systems (Runger *et al*., 1996; Montgomery and Mastrangelo, 1991; Mason *et al*., 1997). Meanwhile, Wang and Zhang (2008) claimed that control chart are also not very sensitive to the small casual changes in the data. Therefore, this study would like to use CC to identify the pattern of process variability based on preliminary data input.

MATERIALS AND METHODS

This case study was done in an offshore manufacturing plant that produces microprocessor products. The manufacturer uses top plates and tim adhesive line to detect defect on production line. This study used CC in detecting defect of sample product as a quality control process. The CC consists of three lines; an Upper Control Limit (UCL), a Lower Control Limit (LCL) and a Center Line (CL). The UCL and LCL are the maximum and minimum values for a process characteristic to be considered in control while the center line is the mean value for the process. These limits are arbitrarily established at three standard deviations above and below the center line. The software used is MiniTAB16.

The scope of the study was on attribute of non-conformity data and forty lots sample products used in this study. The tools used were special top plate and the tim, adhesive production line and finally CC to chart the control line of sample products. The data type was attributed with variable subgroup size and the sample number of the data was unequal. Finally, u-chart was based on average sample size where it was used in this study based on the following equation:

$$\text{Control limits} = \bar{u} \pm 3\sqrt{\frac{\bar{u}}{\bar{n}}}$$

Where:

$$\bar{u} = \frac{\sum_{i=1}^{m} c_i}{\sum_{i=1}^{m} n_i}$$

And:

$$\bar{n} = \frac{\sum_{i=1}^{m} n_i}{m_i}$$

RESULTS AND DISCUSSION

The result of the study is divided into five sections; defect identification by using special top plates; defect identification by using Tim and Adhesive line; application of cc for identifying control line (special top plates); application of CC for identifying control line (Tim and Adhesive line) and finally line 5 used of CC for revised data.

Defect identification by using special top plates: Forty lots of sample were placed on a top plate for defect observation and the result shows that out of 40 lots or 31971 samples, 514 of them found as defect. The detail is on Table 1, Column 3, No. defect before (B).

Defect identification by using Tim and Adhesive line: The same samples will go through another quality control tool is called Tim and Adhesive line as the result shows that the number of sample defect is increasing from 514-664 after going through Tim and Adhesive line. The detail is on Table 1 (Column 4, No. Defect after (A)).

This manufacturer does not CC application as their quality control production. Their current practice once the sample defect identified, the production engineer will identify the cause of the defect by inspecting one by one the defect sample and decide either to correct it or reject it. The weaknesses of this method that the identifying which defect sample need to correct or reject takes time and sometimes they may make a wrong decision especially for a new production engineer. Finally, this method is not suitable for mass production manufacturers. Base on the limitation of both methods, therefore this study used CC to improve process of identifying the accepted and rejected the defect products.

Application of CC for identifying control line (special top plates): The defect sample data was analyzed by using MiniTab16 and the control limits and center line were determined. This study used u-chart based on average sample size, the equation as:

$$\text{Control limits} = \bar{u} \pm 3\sqrt{\frac{\bar{u}}{\bar{n}}}$$

Where:

$$\bar{u} = \frac{\sum_{i=1}^{m} c_i}{\sum_{i=1}^{m} n_i}$$

And:

$$\bar{n} = \frac{\sum_{i=1}^{m} n_i}{m_i}$$

The result showed in Table 1 where as the Control Line (CL) in Column 5; Lower Control Line (LCL) in Column 7 and Upper Control Line (UCL) in Column 9 result showed in Table 1; for first method using special

Table 1: Control chart data (top plate and Tim and Adhesive line)

		No. defect		CL		LCL		UCL	
SN	TQ	B	A	B	A	B	A	B	A
1	798	11	15	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
2	800	15	19	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
3	799	14	18	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
4	800	18	22	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
5	800	10	16	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
6	798	15	18	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
7	800	16	25	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
8	799	16	24	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
9	800	14	16	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
10	800	14	30	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
11	798	13	17	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
12	799	12	16	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
13	800	16	17	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
14	800	11	14	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
15	800	10	12	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
16	798	16	17	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
17	800	15	19	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
18	800	11	16	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
19	799	12	14	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
20	800	16	18	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
21	800	20	20	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
22	800	10	13	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
23	799	15	16	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
24	800	14	16	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
25	800	7	10	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
26	797	9	13	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
27	798	16	18	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
28	798	14	15	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
29	799	10	11	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
30	800	10	29	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
31	800	12	14	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
32	800	11	15	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
33	798	10	12	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
34	798	14	16	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
35	800	14	18	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
36	799	11	12	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
37	797	15	16	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
38	800	10	12	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
39	800	8	11	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
40	800	9	14	0.0161	0.0208	0.002635	0.005496	0.029564	0.036103
Total	31971	514	664	0.0161	0.0208		0.005496		

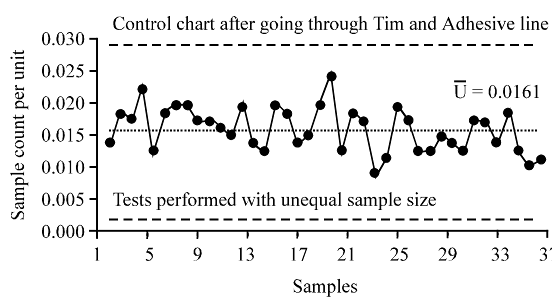

Fig. 1: Control chart for using special top plates

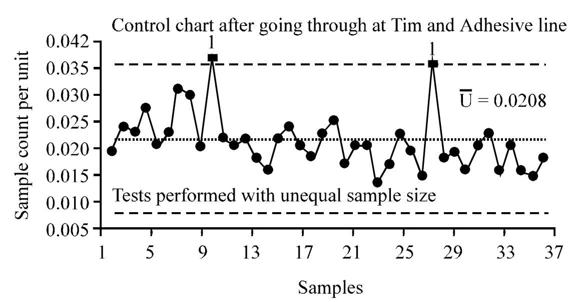

Fig. 2: Control chart after going through Tim and Adhesive line

top plate column. Based on with center line at = 0.0161 is plotted on a u-chart by using MiniTab16, the result presented in Fig. 1.

From Fig. 2, it identified that all samples of microprocessor are within the control limit and they present a reasonably random pattern around $\bar{u}$. Hence, the defect products that identified by using special top plate (Colum 3, Table 1) is said to be in control, meaning that the defect is accepted. Therefore, all correction will be done on the particular samples.

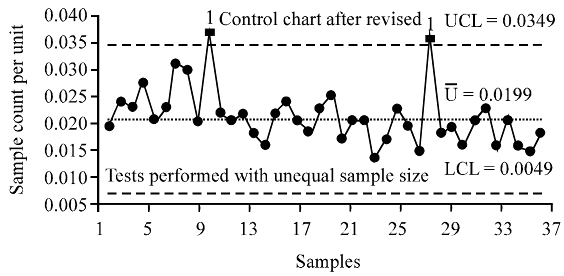

Fig. 3: Control chart after revised

Application of CC for identifying control line (Tim and Adhesive line): As shown on Table 1, Column 4, the number of defect increases after the sample products were going through Tim and Adhesive production line. Once again, CC was used to identify if the defect is under control in line or vice versa.

The control chart as shown in Table 1, Column 6 at 0.0208 with lower (Column 8) and upper (Column 10) control limits. The result is shown in Fig. 3. The result shows that sample fraction non-conformity is plotted on this chart. It is noted that two points, those from sample 10 and 30, plot above the upper control limit, so the proportion of defects were not within the control limits. These points must be investigated to observe an assignable cause that can be determined.

Used of CC for revised data: Assuming assignable cause, the control limits were revised. Sample 10 and 30 were eliminated from the control limits calculation and the new center line and revised control limits were calculated. Revised of CL was done by using the following equation:

$$\bar{n} = \frac{\sum n_i}{\sum k_i} = \frac{31971-800-800}{40-2} = \frac{30371}{38} = 799.236$$

$$\bar{u} = \frac{\sum c_i}{\sum n_i} = \frac{664 -30-29}{31971-800-800} = 0.0199$$

CL = 0.0199; UCL = 0.0349; LCL = 0.0049. The revised center line and control limits are shown on Fig. 3 are not dropped sample 10 and 30 the chart. It indicates unusual points, process adjustments or the type of investigation made at a particular point in time forms a useful record for future process analysis and should become a standard practice in control chart usage.

As shown in the all of the sample of products defect are under the control line, therefore, it can be concluded that these new control limits can be used for future samples. The control limits (0.0049, 0.0349) were adopted as trial control limits for use in the following month where monitoring of future production is of interest. The center line of 0.0199 is considered as the mean of the process.

CONCLUSION

Based on the above result, it can be concluded that the use of CC could help the manufacturers to identify the overall performance of the samples which can be controlled before and after the process of Tim and Adhesive line. It showed that the samples can be revised for data that were out of control. This is done in order to ensure that the center line and the control limits of the same sample can be used for the following months. In a nutshell, the control chart is an essential tool for continuous quality control. Even though the findings of this study are applicable but there still exist some limitations such as the inability to identify possible causes of defect. This is due to many reasons for the defect such as a failure or defect in a single component or through an interaction between multiple components in a system. Other reasons could be related to a component's inputs (e.g., raw material, processing conditions, loading conditions, environment, etc). Therefore, future studies are needed, especially in identifying the possible reasons for defect which will eventually contribute to the process simplification. For example, companies can come out with a system that is more user friendly for those who do not have statistic backgrounds.

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