CHAPTER 5
Test of model

In this chapter, the testing of the developed model will be tested to prove that the model can work well to detect the shift in mean of the process. Due to the theory of the p-chart, control limits of this chart are based on mean of the process and the sample size. But as we described in the previous chapter that the sample size of the electric tester is constant to 50, so only the shift of process mean will be concerned. So, the detection of mean of the process will leads to the suitable point to change the control limits.

5.1 Testing procedure

1) Input data to the spreadsheet program.
2) Find the point that indicate the shift of the process by use the hypothesis test that is described in the model.
3) Compare to the real visual system.

The spreadsheet program that is used in this chapter is Microsoft Excel.

The testing processes are divided into 3 sections that are.
❏ Test with the generated random data.
❏ Test with actual data form the manufacturing process.
❏ Compare with the current method.

5.2 Generate random data.

As mentioned in the previous chapter, the randomly generated data is very important to ensure that the model works in the right way before going to the further step. The generated random data is generating from computer software named Microsoft Excel which is a very powerful spreadsheet calculation software. The generating is set to generate of binomial distribution number to be the analysed data. This is because the data that used to analyse in p-chart came from the "success" or

"failure" of the test in each tester, so the binomial distribution number is generated randomly. The generation procedure is described below

Generate data that has mean of 0.4, which means the average number of the fraction nonconforming is 40 percent.

Generate the data that has mean 0.1 to see notice to test whether the logic of this model is correct or not. The change from 0.4 to 0.1 of the process mean has to be detected by the model. If the model cannot detect this change, it means this model cannot work properly in the actual manufacturing system.

Change some point of data to see whether this model can detect the single shift of the data or not. If this kind of points can be detected, we will prove that after the elimination of this point of data, the model can still calculate the mean correctly or not. This is also testing the detection of the shift of process mean.

The table below shows the data that is randomly generated by computer which has p value of 0.4. This will be used to test the model.

**Table 5-1 Randomly generated data with p value = 0.4**

0.31	0.45	0.37	0.39	0.4	0.32
0.43	0.45	0.4	0.47	0.42	0.38
0.46	0.4	0.34	0.33	0.43	0.3
0.4	0.48	0.37	0.37	0.44	0.42
0.34	0.45	0.51	0.45	0.42	0.42

The next table will shows the data that is randomly generated by computer which has p value of 0.1. This will be used to test the model if the model can detect the shift of the process mean or not.

Table 5-2 Randomly generated data with p value = 0.1

0.04	0.07	0.17	0.07	0.13	0.17	0.12	0.07	0.12	0.07
0.1	0.14	0.09	0.11	0.13	0.1	0.06	0.09	0.16	0.12
0.07	0.08	0.18	0.09	0.1	0.12	0.11	0.08	0.07	0.06
0.09	0.09	0.06	0.14	0.06	0.1	0.08	0.08	0.19	0.09
0.11	0.06	0.08	0.09	0.1	0.13	0.11	0.11	0.08	0.08
0.09	0.07	0.12	0.06	0.08	0.13	0.06	0.1	0.13	0.08
0.1	0.12	0.1	0.11	0.12	0.08	0.1	0.16	0.1	0.12
0.1	0.14	0.09	0.1	0.12	0.07	0.04	0.05	0.08	0.07
0.11	0.08	0.12	0.04	0.07	0.09	0.09	0.07	0.09	0.15
0.09	0.09	0.06	0.16	0.12	0.07	0.12	0.11	0.14	0.06

From the first set of data which is the first 30 point of data, we will calculate trial control limits and the center line will be set as p_0. The control chart will be plotted below to show any points that beyond the control limits.
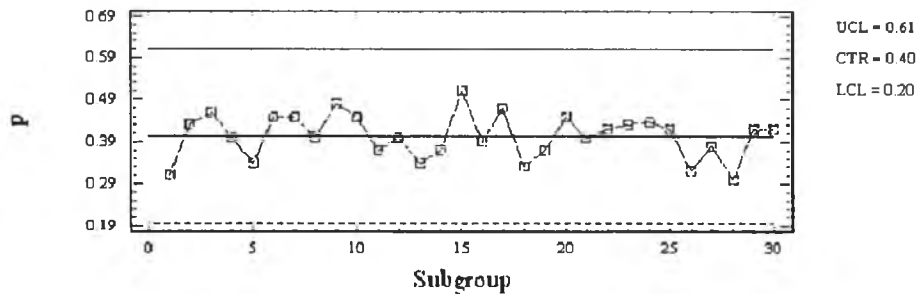
Figure 5-1 Trial control limits of the randomly generated data

At this stage, we will specify α, β, and $\dfrac{\delta}{\sigma}$. The α will be set as 95% confident level, β will be set to be 60% and $\dfrac{\delta}{\sigma}$ will be set to 1. So, the $Z_{\alpha/2}$ is equal to 1.96 and Z_β is equal to 0.25 The sample size for the next stage will be calculated by the formula above and shown below.

From the calculation, the value of σ is equal to 0.069, so the δ will be 0.069, so we can find the expected p value to be $p_0 + \delta = 0.469$.

$$n = \left(\frac{1.96\sqrt{0.4(1-0.4)} + 0.25\sqrt{0.469(1-0.469)}}{0.069} \right)^2$$

After we know all the variable in the calculation formula, we can find the sample size which is equal to 200 which means we have to take another 200 sample to find the next process mean shift. Due to the sample taken in the process will take 50 sample in each point, 200 sample is equal to 5 data points.

The next process is to find the average p value of the next 5 points and test hypothesis with the standard p value with the same confident level indicated above, 95%. The average p for the first 11 points of the next set of data is equal to 0.082, so the Z value will be calculated as shown below.

$$Z_0 = \frac{0.082 - 0.4}{\sqrt{0.4(1-0.4)/200}} = -12.12$$

From the calculation, the $|Z_0| > Z_{\alpha/2}$, which is equal to 1.96, so we will reject H_0, so this is the point to shift the process mean.

After that, we continue with the next set of data. From the calculation, the sample size of this set of data will require sample size equal to 483 sample or 10 data points. The average p value of the next 10 data point is 0.101.

$$Z_0 = \frac{0.093 - 0.082}{\sqrt{0.082(1-0.082)/483}} = 0.83$$

From the calculation, the next 10 data points and the current set of data has no significantly difference in process mean, so we will continue use this control limits until we can find any difference.

We can plot the control chart of this set of data to see the change in control limits at the points that we detect the change.
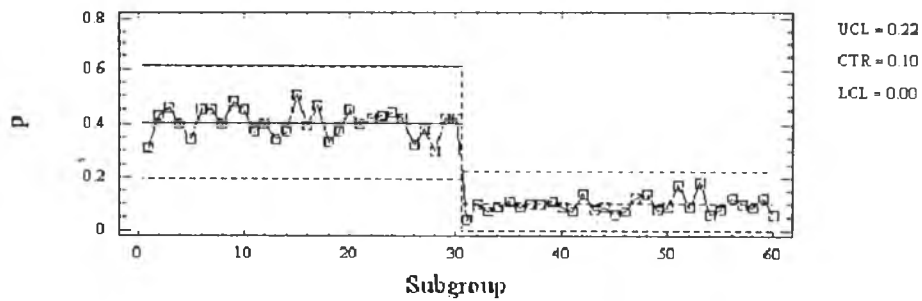
Figure 5-2 The control chart of the randomly generated data

5.3 Actual data form the manufacturing process.

The data below is the data that is taken from the actual manufacturing line. The data used in this test came from one of the electric tester of 5 days and 2 shifts of manufacturing.
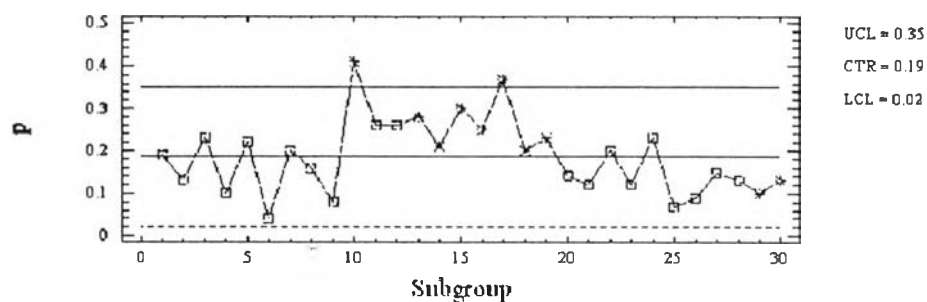
Table 5-3 The actual data from the real manufacturing process from top to bottom and left to right respectively.

Day 1	Day 2	Day 3	Day 4	Day 5
0.19	0.07	0.11	0.14	0.18
0.13	0.09	0.28	0.15	0.22
0.23	0.15	0.21	0.15	0.18
0.1	0.13	0.07	0.38	0.24
0.22	0.1	0.18	0.4	0.19
0.04	0.13	0.24	0.3	0.19
0.2	0.08	0.2	0.21	0.18
0.16	0.18	0.06	0.15	0.21
0.08	0.23	0.17	0.27	0.21
0.41	0.3	0.13	0.28	0.19
0.26	0.1	0.2	0.23	0.19
0.26	0.19	0.27	0.18	0.23
0.28	0.03	0.17	0.29	0.22
0.21	0.14	0.13	0.23	0.16
0.3	0.17	0.16	0.17	0.21

| 0.25	0.12	0.16	0.24	0.25
0.37	0.14	0.27	0.24	0.19
0.2	0.11	0.24	0.1	0.27
0.23	0.18	0.2	0.24	0.19
0.14	0.14	0.2	0.1	0.29
0.12	0.15	0.26	0.24	0.43
0.2	0.14	0.21	0.24	0.34
0.12	0.09	0.17	0.2	0.27
0.23	0.13	0.24	0.23	0.16

Plot trial control limits and check whether there is any out of control points.

From this set of data, the first 30 points is plotted in control chart that shown below.

Figure 5-3 Trial control chart of the actual data from manufacturing

From the figure above, there are 2 out of control points that has to be eliminated. After the elimination of these 2 points, we have to collect more 2 points to calculate the trial control limits. The figure of this new control chart is shown below.
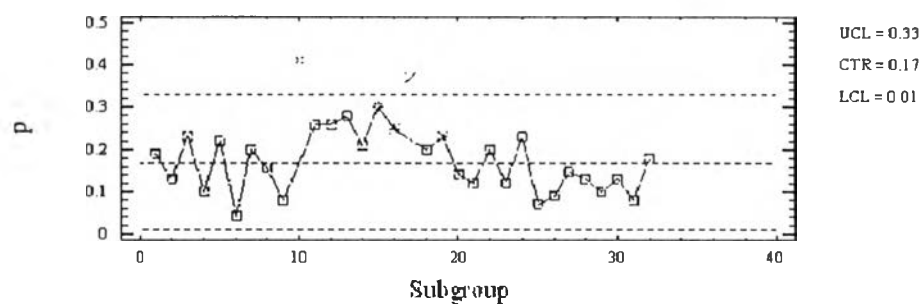
Figure 5-4 Trial control chart of the actual data from manufacturing after eliminate the out of control points.

After the trial control limits were created, the next process will begin. The calculation of sample size with $\alpha = 95\%$, $\beta = 10\%$ and $\dfrac{\delta}{\sigma} = 1$. From the calculation, the result is the sample size is 233, so it means the next 5 data points will be used in the calculation.

For the next 5 points of data, the average p is 0.17. After the hypothesis testing, the null hypothesis is not reject, so we will still use this standard p until we can find the significantly change in process mean. The calculation is shown below.

$$Z_0 = \frac{0.17 - 0.183}{\sqrt{0.183(1 - 0.183)/233}} = -0.51$$

$$|-0.51| < Z_{\alpha/2} = 1.96$$

The next process is to continue checking with other set of data and still found that this control limits can still be used until the data point 73-77.

Table 5-4 Data point 33-77 with Z value

Data point	Value	Z of each group
33	0.23	-0.51311
34	0.3	
35	0.1	
36	0.19	
37	0.03	
38	0.14	-1.85509
39	0.17	
40	0.12	
41	0.14	
42	0.11	
43	0.18	-1.69721
44	0.14	

45	0.15	
46	0.14	
47	0.09	
48	0.13	-0.90781
49	0.11	
50	0.28	
51	0.21	
52	0.07	
53	0.18	-0.51311
54	0.24	
55	0.2	
56	0.06	
57	0.17	
58	0.13	-0.11841
59	0.2	
60	0.27	
61	0.17	
62	0.13	
63	0.16	0.90781
64	0.16	
65	0.27	
66	0.24	
67	0.2	
68	0.2	1.30251
69	0.26	
70	0.21	
71	0.17	
72	0.24	
73	0.14	2.40767
74	0.15	
75	0.15	
76	0.38	
77	0.4	

In the next set of data which is the data point 78-82, there is no out of control point but the z value is indicated that there is process mean shift at this stage.

Table 5-5 Data point 78-82 with Z value

Data point	Value	Z of each group
78	0.3	2.32873
79	0.21	
80	0.15	
81	0.27	
82	0.28	

At this stage, the null hypothesis is rejected, so we can conclude that the process mean is shifted and the new calculation of sample size and control limits occurred at this point.

The new sample size from the calculation is 541 sample size which means 11 data points and the new control limits is calculated as shown below.

Table 5-6 Control limits of data point 78-82

Data Point	78-82
UCL	0.42
Center Line	0.24
LCL	0.06

The next tabe will shows the rest of data with the calcualted z value in each group.

Table 5-7 Data point 83-120 with Z value

Data point	Value	Z of each group

83	0.23	-1.88135
84	0.18	
85	0.29	
86	0.23	
87	0.17	
88	0.24	
89	0.24	
90	0.1	
91	0.24	
92	0.1	
93	0.24	
94	0.24	-1.88135
95	0.2	
96	0.23	
97	0.18	
98	0.22	
99	0.18	
100	0.24	
101	0.19	
102	0.19	
103	0.18	
104	0.21	
105	0.21	-1.6338
106	0.19	
107	0.19	
108	0.23	
109	0.22	
110	0.16	
111	0.21	
112	0.25	
113	0.19	
114	0.27	
115	0.19	

116	0.29	3.156868
117	0.43	
118	0.34	
119	0.27	
120	0.16	

In the last subgroup, the Z value is higher than 1.96n which means the null hypothesis is rejected but when look at the data, there is 1 out of control point that has to be eliminated. After the elimination of this data, the Z value become 1.3614 which is less than 1.96. So, this set of data is not the set that is the change of process mean.

The continuous control chart of this set of data is shown below.
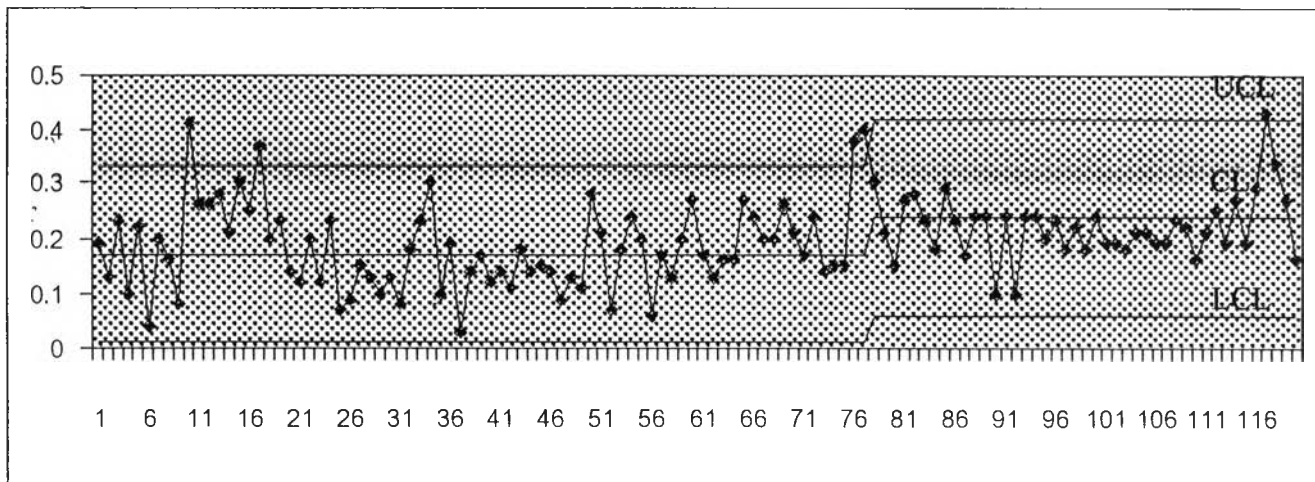
Figure 5-5 The control chart of this proposed model

## 5.4 Compare with the existing control system

With respect to figure 5-5, if human judgement is used in determining when the control limits and center line should be recalculate, different people will have different opinion. However with the proposed algorithm, the judgement will be at the same standard in every time since human judgement is removed. In a typical practice, computer software is often used to adjust the control limits. The adjustment can be performed every shift of production by calculating control limits and center line base on data from last 2 shifts. Using the same set of data, a comparison between the mention practice and the proposed model is performed and discussed as follow.

1. The control charts that use the same data as the previous chart but change control limits and center line after the prove that there is significantly difference among the set of data.
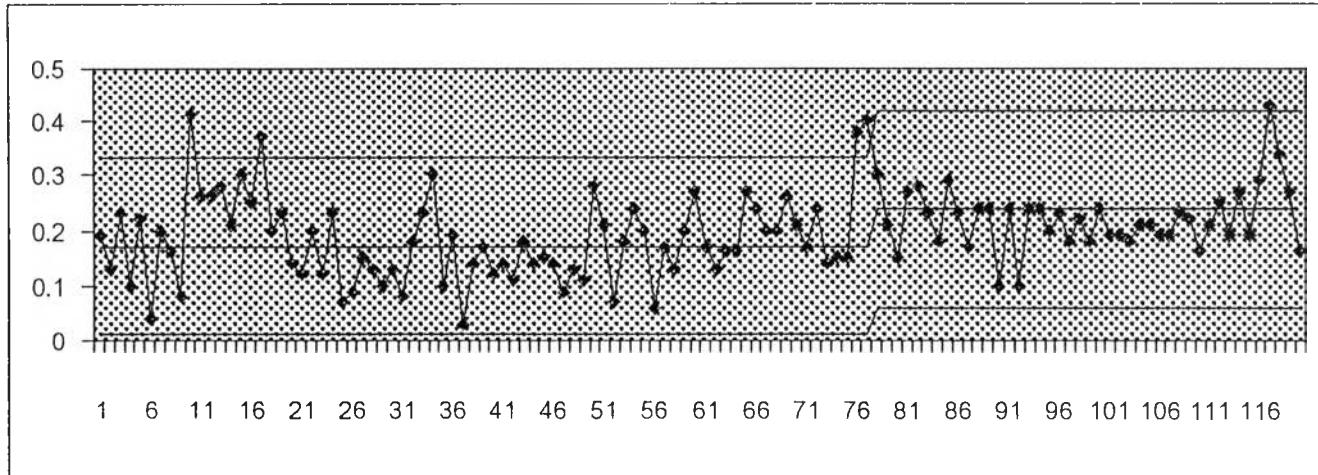

Figure 5-6 Control chart that use the proposed model.

2. The control chart that use the same set of data as the previous two charts. This chart use existing control process of the factory.
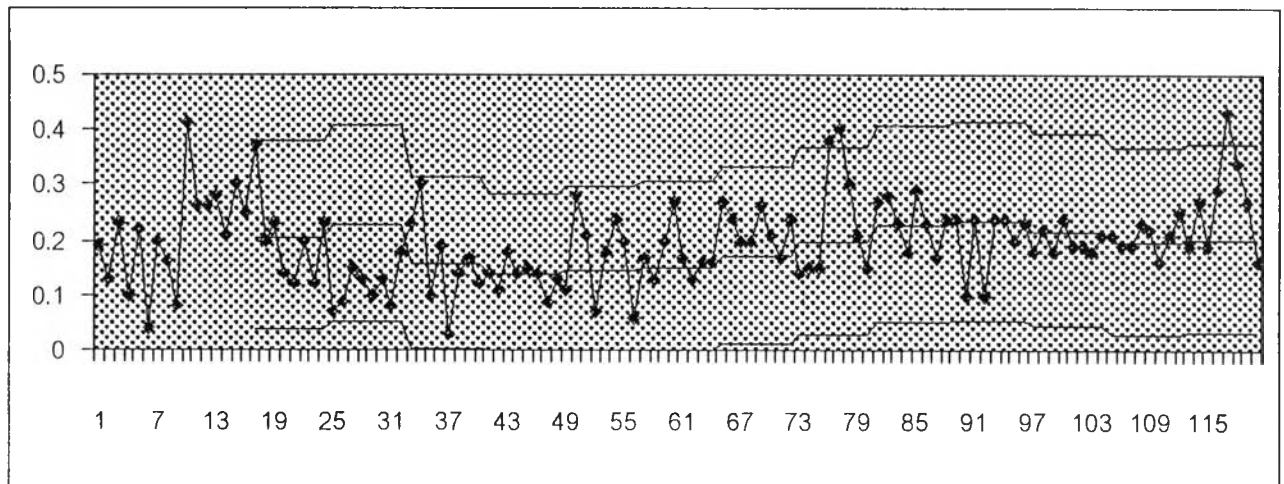
Figure 5-7 Control chart with current control process

3. The control chart of data from actual manufacturing. This chart uses the control limits from the calculation of first 30 points to set up the control limits and center line. Then, maintain the control limits and center line until last points of data.
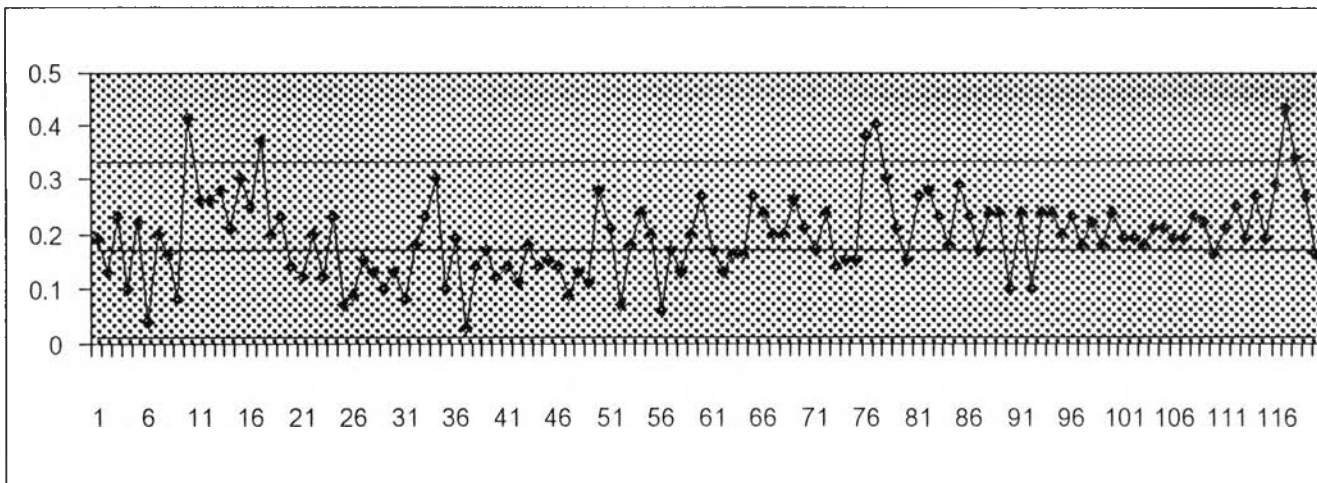
Figure 5-8 The control chart that maintain the same control limits until last points.

From figure 5-5, if we look at only this control process, we can see just only the change in control limits and center line in every shifts, not the actual change in process mean which we consider. With the proposed algorithm, the picture is shown in figure 5-6. It shows the change in control limits and center line only when process mean and variation have shifted to new value, not every shift of operation. This proposed algorithm can be used in continuously control because the control limits and center line will be automatically changed when process mean and variation shifted. Figure 5-7 shows the conventional Shewhart attribute control chart, no control limits and center line change automatically. This type of control needs human judgement to make the decision whether the control limits and process mean have shifted to new the level or not.