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Performance of Attribute Charts and Fuzzy Control Chart for Variable Data

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ABSTRACT: The Quality has evolved through a number of stages such as inspection, quality control, quality assurance, and total quality control and the results produced by the above stages are used to control and improve the manufacturing process. Statistical process control (SPC) is a powerful collection of problem solving tools useful in achieving process stability and improving capability through the reduction of variability.SPC can be applied to any process. A control chart is a statistical tool used to distinguish between variations in a process resulting from common causes and variation resulting from special causes. One of the basic control charts is *p* -chart. For the quality related characteristics such as characteristics for appearance, softness, color, taste, etc., attribute control charts such as p-chart, c -chart are used to monitor the production process. The p -chart is used to monitor the process based upon the fraction In classical *p* -charts, each item classifies as either "nonconforming" or "conforming" to the specification with respect to the quality characteristic. Another attribute chart is CUSUM (cumulative sum) chart which can be used during smaller shifts occur. For many problems control limits could not be so precise .uncertainty comes from the measurement system including operators, environmental conditions etc .In this situation fuzzy set theory is a useful tool to handle this uncertainty Fuzzy control limits provide a more accurate and flexible evaluation. In this paper the attributes charts like p- chart and CUSUM chart and also fuzzy α cut control chart for standard deviation are constructed for the variable data to improve the process

KEYWORDS: Attribute charts, *p* -chart, CUSUM, fuzzy α cut and α –level fuzzy mid range

I. INTRODUCTION

Statistical Process Control (SPC) is used to monitor the process stability which ensures the predictability of the process. The power of control charts lies in their ability to detect process shift and to identify abnormal conditions in the process. In 1924, Walter Shewhart designed the first control chart. According to him, if w be a sample statistic that measures some quality characteristic of interest the mean of w is μw, and the standard deviation of w is σw, then the center line (CL), the upper control limit (UCL) and the lower control limit (LCL) are defined as

$$UCL = \mu w + d\sigma w$$

$$LCL = \mu w - d\sigma w$$

where d is the "distance" of the control limits from the center line, expressed in standard deviation units. A single measurable quality characteristic such as dimension, weight or volume is called a variable. In such cases, control charts for variables are used to monitor the process. These include the X-chart for controlling the process average and the R -chart (or S -chart) for controlling the process variability. For the quality-related characteristics such as characteristics for appearance, softness, color, taste, etc., attribute control charts such as p-chart, c-chart are used to monitor the production process. Sometimes the product units are classified as either "conforming" or "nonconforming", depending upon whether or not product units meet some specifications. The p -chart is used to monitor the process based upon the fraction of non conforming units.

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Many quality characteristics cannot be conveniently represented numerically. In such cases we usually classify each item inspected as either conforming or non conforming to the specifications on that quality characteristics. **Numerical Example:**

In practice, one may classify each item in more than two categories such as "bad", "medium", "good", and "excellent". On a production line, a visual control of the particular product might have the following assessment possibilities

1. "Reject" if the product does not work;.
2. "Poor quality" if the product works but has some defects;
3. "Medium quality" if the product works and has no defects, but it has some aesthetic flaws;
4. "Good quality" if the product works and has no defects, but has few aesthetic flaws;
5. "Excellent quality" if the product works and has neither defects nor aesthetic flaws of any kind.

To monitor the quality of this product, 10 samples of different sizes are selected. The degrees of membership for the above assessment are taken as 1, 0.75, 0.5, 0.25 and 0 respectively. The data with $\widetilde{L}i$ and p_iˆ are given in Table –1.

$\widetilde{L}i = \sum_{i=1}^{k} Ximi / \sum_{i=1}^{k} Xi = \sum_{i=1}^{k} Ximi / nr, nr \in \{n1, n2, ...ns\}$ $\widetilde{L1}$ = {(0x1) + (3x0.75)+(8x0.5)+ (19x0.25)+(0x0)}/30 = **0.36**

$\widetilde{L2}$ = {(0x1) + (4x0.75)+(7x0.5)+ (10x0.25)+(4x0)}/25 = **0.36**

$\widetilde{L3}$ = {(5x1) + (3x0.75)+(8x0.5)+ (12x0.25)+(7x0)}/35 = **0.40** and so on,

The value of $P_{i,}$ the control limits for p-charts can be calculated as, $\hat{P}i = Di / nr$ $\hat{P}1$=0, $\hat{P}2$=0, $\hat{P}3$=0.142 and so on.

Table 1: The data of various sample size and the values of $\widetilde{L}i$ and $\widehat{Pi}$

Sample size	Reject	Poor quality	Medium quality	Good quality	Excellent quality	$\widetilde{L}i$	$\widehat{Pi}$
30	0	3	8	19	0	0.36	0
25	0	4	7	10	4	0.36	0
35	5	3	8	12	7	0.407	0.14
30	0	0	10	20	0	0.33	0
40	8	11	9	7	5	0.36	0.2
35	7	5	8	10	5	0.49	0.2
25	2	4	9	7	3	0.45	0.08
40	6	13	9	6	6	0.54	0.15
30	0	0	0	2	28	0.016	0
45	0	2	18	15	10	0.316	0

For sample 1:

$$UCL_1 = \overline{P} + D\frac{\sqrt{\overline{P}}\left(1-\overline{P}\right)}{n_r} = 0.22$$

$$CL_1 = \overline{P} = 0.08$$

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$LCL_1 = \overline{P} - D\frac{\sqrt{\overline{P}}\left(1-\overline{P}\right)}{n_r} = -0.06$ and so on.

The chart given below depicts the conventional p – chart for 10 samples

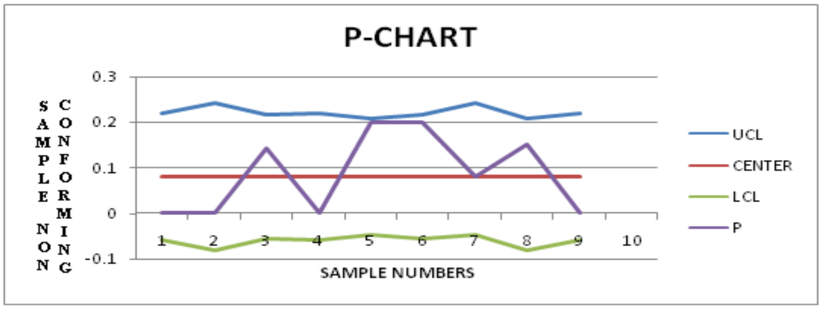

Fig.1 P- chart for 10 samples

In fig.1 out of control signal is not seen corresponding to the 10 samples. So the process is under control

II. CUSUM CHART

The cusum chart directly incorporates all the information in the sequence of sample values by plotting the cumulative sums of the deviations of the sample values from a target value. For example, suppose that samples of size $n \geq 1$ are connected, and $\overline{x_j}$ is the average of the j^{th} sample. Then if μ_0 is the target for the process mean, the cumulative sum control chart is formed by plotting the quantity

$$C_i = \sum_{j=1}^{i}\left(\overline{x}_j - \mu_0\right)$$

Against the sample i. C_i is called the cumulative sum up to and including the i^{th} sample. Because they combine information from several samples, cumulative sum charts are more effective than Shewhart charts for detecting small process shifts. Cumulative sum control charts were first proposed by Page (1954) and have been studied by many authors; in particular, see Ewan (1963), Page (1961), Gan (1991), Lucas (1976), Hawkins (1981) (1993a), and Woodall and Adams (1993). In this section we concentrate on the cumulative sum chart for the process mean. It is possible to devise cumulative sum procedures for other variables, such as Poisson and binomial variables for modeling nonconformities and process fallout. We will show subsequently how the cusum can be used for monitoring process variability.

Let x_i be the i^{th} observation on the process. When the process is in control, x_i has a normal distribution with mean μ_0 and standard deviation σ. We assume that either σ is known or that an estimate is available. Later we will discuss monitoring σ with a cusum.

The tabular cusum works by accumulating derivations from μ_0 that are above target with one statistics C^+ and accumulating derivations from μ_0 that are below target with another statistic C^-. The statistics C^+ and C^- are called one-sided upper and lower cusum, respectively. They are computed as follows.

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The Tabular Cusum:

$$C_i^+ = \max\left[0, x_i - (\mu_0 + K) + C_{i-1}^+\right]$$

$$C_i^- = \max\left[0, (\mu_0 - K) - x_i + C_{i-1}^-\right]$$

Where the starting values are $C_0^+ = C_0^- = 0$

Table 2 presents the tabular cusum scheme. To illustrate the calculations, consider period.

1. The equations for C^+_I and C^-_I are $C_I^+ = \max\left[0, x_1 - 122 + C_0^+\right]$ and C_I^- are $C_I^- = \max\left[0, 121.5 - x_1 + C_0^-\right]$ Since $K = 0.5$ and $\mu_0 = 122$ now $x_1 = 122.63$. Since $C_0^+ = C_0^- = 0$ $C_I^+ = 0.13$ and $C_I^- = 0$.

Table 2 The Tabular Cusum

Period i	x_i	$x_i - 122$	c_i^+	$125.5 - x_i$	c_i^-
1	122.63	0.63	0.13	− 1.13	0
2	122.74	0.74	0.37	− 1.24	0
3	122.90	0.90	0.77	− 1.4	0
4	123.20	1.20	1.47	− 1.7	0
5	123.00	1	1.97	− 1.5	0
6	122.40	0.40	1.87	− 0.9	0
7	123.15	1.15	2.52	− 1.65	0
8	123.08	1.08	3.1	− 1.58	0
9	122.52	0.52	3.12	− 1.02	0
10	122.75	0.75	3.37	− 1.25	0
11	122.90	0.90	3.37	− 1.4	0
12	122.93	0.93	4.2	− 1.43	0
13	122.36	0.36	4.06	− 0.86	0

III. RESULT

The cusum calculations in table 2 show that the upper side cusum at period 15 is $C_{15}^+ = 5.76$. Since this is the first period at which $C_i^+ > H = 5$, we would conclude that the process is out of control at that point

IV. FUZZY $\tilde{\bar{X}}$ CONTROL CHART BASED ON STANDARD DEVIATION

The Shewhart $\bar{X}$ chart based on standard deviation is given below

$UCL_{\bar{X}} = \bar{\bar{X}} + A_3\bar{S}$, $CL_{\bar{X}} = \bar{\bar{X}}$, $LCL_{\bar{X}} = \bar{\bar{X}} - A_3\bar{S}$ Where A_3 is a control chart co-efficient (Kolarik 1995)

The value of $\bar{S}$ is

$$S_j = \sqrt{\frac{\sum_{i=1}^{n}\left(x_{ij} - \bar{X}_j\right)^2}{n-1}}$$

$$\bar{S} = \frac{\sum_{j=1}^{m} s_j}{m}$$

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Where S_j is the standard deviation of sample *j* and $\bar{S}$ is the average of S_j's.

Application: Different Observation data have been considered with 10 samples. Fuzzy control limits are calculated according to the procedures. For $n = 5,\ A_2 = 0.577$ Where A_2 is obtained from the coefficients table for variable control charts

Table: 3

Samples No	X_a					X_b				
	1	2	3	4	5	1	2	3	4	5
1	122.36	122.82	122.24	122.82	122.94	122.54	122.82	122.32	122.65	123.14
2	122.48	122.40	122.70	122.90	123.34	122.52	123.01	122.56	122.98	122.75
3	122.42	122.74	123	123.22	123.12	123.55	122.03	122.63	122.85	122.96
4	123.42	122.96	123.84	123.02	122.76	122.36	122.52	122.58	123.58	123.05
5	122.48	123.10	123.26	123.34	122.82	123.05	122.96	122.85	123.25	123.01
6	123.04	122	121.80	122.66	122.76	122.85	122.45	122.78	122.56	122.69
7	122.75	122.62	123.82	123.10	123.46	123.02	122.69	122.85	122.63	122.45
8	123.32	122.92	122.90	122.94	123.36	122.89	122.96	122.35	123.35	122.56
9	123	123.35	123.40	123.45	123.67	122.63	122.86	123.56	123.56	122.63
10	122.80	122.84	123.10	122.24	122.80	123.23	122.69	122.68	122.68	122.1
Samples No	Xc					Xd				
	1	2	3	4	5	1	2	3	4	5
1	123.02	122.54	122.69	122.86	123.25	123.02	122.96	122.81	123.12	122.79
2	122.96	123.26	122.86	122.26	123.09	122.55	123.08	122.91	123.07	122.56
3	122.56	122.36	122.96	123.08	123.19	122.63	122.97	123.05	122.45	123.75
4	123.0	122.56	122.81	122.19	123.08	122.82	122.56	122.79	123.11	123.01
5	122.45	122.49	122.56	122.86	122.46	122.56	122.71	122.82	122.97	123.04
6	122.86	122.79	122.56	123.05	122.53	123.07	123.11	122.91	122.85	122.56
7	123.56	122.96	122.86	122.91	123.05	122.55	122.71	123.05	122.91	122.75
8	123.05	123.08	122.96	122.45	122.81	123.15	123.01	122.82	122.55	122.79
9	122.56	122.49	122.79	122.63	122.82	123.03	122.91	122.67	122.79	122.54
10	123.01	122.93	122.73	122.83	122.91	122.49	122.67	122.82	123.11	123.07

V. FUZZY $\bar{\bar{X}}$ CONTROL CHART BASED ON STANDARD DEVIATION

The theoretical structure of fuzzy $\bar{\bar{X}}$ control chart and fuzzy $\bar{S}$ control chart has been developed by Senturk and Erginel (2009). The fuzzy $\bar{S}_j$ is the standard deviation of sample j and it is calculated as follows

$$S_j = \sqrt{\frac{\sum_{i=1}^{n}\left[\left(X_a, X_b, X_c, X_d\right)_{ij} - \left(\bar{X}_a, \bar{X}_b, \bar{X}_c, \bar{X}_d\right)_j\right]^2}{n-1}}$$

and the fuzzy average is calculated by using standard deviation represented by the following Trapezoidal fuzzy number

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$$\tilde{\bar{S}} = \left\{ \frac{\sum_{j=1}^{m} S_{aj}}{m}, \frac{\sum_{j=1}^{m} S_{bj}}{m}, \frac{\sum_{j=1}^{m} S_{cj}}{m}, \frac{\sum_{j=1}^{m} S_{dj}}{m} \right\} \quad = \left(\bar{S}_a, \bar{S}_b, \bar{S}_c, \bar{S}_d\right)$$

and the control limits of fuzzy $\tilde{\bar{X}}$ control chart based on standard deviation are defined as follows

$$U\tilde{C}L_{\bar{X}} = \tilde{C}L + A_2\bar{R} = \left(\bar{\bar{X}}_a, \bar{\bar{X}}_b, \bar{\bar{X}}_c, \bar{\bar{X}}_d\right) + A_2\left(\bar{S}_a, \bar{S}_b, \bar{S}_c, \bar{S}_d\right)$$

$$= \left(\bar{\bar{X}}_a + A_2\bar{S}_a, \bar{\bar{X}}_b + A_2\bar{S}_b, \bar{\bar{X}}_c + A_2\bar{S}_c, \bar{\bar{X}}_d + A_2\bar{S}_d\right)$$

$$= \left(U\tilde{C}L_1, U\tilde{C}L_2, U\tilde{C}L_3, U\tilde{C}L_4\right)$$

$$= (123.16, 122.97, 122.95, 123.00)$$

$$\tilde{C}L_{\bar{X}} = \left(\bar{\bar{X}}_a, \bar{\bar{X}}_b, \bar{\bar{X}}_c, \bar{\bar{X}}_d\right)$$

$$= \left(\tilde{C}L_1, \tilde{C}L_2, \tilde{C}L_3, \tilde{C}L_4\right)$$

$$= (122.92, 122.77, 122.80, 122.85)$$

$$L\tilde{C}L_{\bar{X}} = C\tilde{L} - A_2\bar{S}$$

$$= \left(\bar{\bar{X}}_a, \bar{\bar{X}}_b, \bar{\bar{X}}_c, \bar{\bar{X}}_d\right) - A_2\left(\bar{S}_a, \bar{S}_b, \bar{S}_c, \bar{S}_d\right) = \left(\bar{\bar{X}}_a - A_2\bar{S}_a, \bar{\bar{X}}_b - A_2\bar{S}_b - \bar{\bar{X}}_c - A_2\bar{S}_c, \bar{\bar{X}}_d - A_2\bar{S}_d\right)$$

$$= \left(L\tilde{C}L_1, L\tilde{C}L_2, L\tilde{C}L_3, L\tilde{C}L_4\right)$$

$$= (122.67, 122.56, 122.64, 122.70)$$

Control Limits For α – Cut Fuzzy $\tilde{\bar{X}}$ Control Chart Based On Standard Deviation

The control limits for α - Cut Fuzzy $\tilde{\bar{X}}$ control chart based on standard deviation are obtained as follows

$$U\tilde{C}L^{\alpha}_{\bar{X}} = \left(\bar{\bar{X}}^{\alpha}_a, \bar{\bar{X}}_b, \bar{\bar{X}}_c, \bar{\bar{X}}^{\alpha}_d\right) + A_3\left(\bar{S}^{\alpha}_a, \bar{S}_b, \bar{S}_c, \bar{S}^{\alpha}_d\right) \quad = \left(\bar{\bar{X}}^{\alpha}_a, A_3\bar{S}^{\alpha}_a, \bar{\bar{X}}_b + A_3\bar{S}_b, \bar{\bar{X}}_c + A_3\bar{S}_c, \bar{\bar{X}}^{\alpha}_d + A_3\bar{S}^{\alpha}_d\right)$$

$$= \left(U\tilde{C}L^{\alpha}_1, U\tilde{C}L_2, U\tilde{C}L_3, U\tilde{C}L^{\alpha}_4\right) = (123.36, 123.26, 123.18, 123.19)$$

$$\tilde{C}L^{\alpha}_{\bar{X}} = \left(\bar{\bar{X}}^{\alpha}_a, \bar{\bar{X}}_b, \bar{\bar{X}}_c, \bar{\bar{X}}^{\alpha}_d\right)$$

$$= \left(\tilde{C}L^{\alpha}_1, \tilde{C}L_2, \tilde{C}L_3, \tilde{C}L^{\alpha}_4\right)$$

$$= (122.83, 122.77, 122.8, 122.822)$$

$$L\tilde{C}L^{\alpha}_{\bar{X}} = \left(\bar{\bar{X}}^{\alpha}_a, \bar{\bar{X}}_b, \bar{\bar{X}}_c, \bar{\bar{X}}^{\alpha}_d\right) - A_3\left(\bar{S}^{\alpha}_a, \bar{S}_b, \bar{S}_c, \bar{S}^{\alpha}_d\right)$$

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$$= \left(\overline{\overline{X}}_a^{\alpha} - A_3 \overline{S}_a^{\alpha}, \overline{\overline{X}}_b - A_3 \overline{S}_b, \overline{\overline{X}}_c - A_3 \overline{S}_c, \overline{\overline{X}}_d^{\alpha} - A_3 \overline{S}_d^{\alpha} \right)$$

$$= \left(LCL_1^{\alpha}, LCL_2, LCL_3, LCL_4^{\alpha} \right)$$

$$= (122.29, 122.27, 122.41, 122.44)$$

Where $\overline{S}_a^{\alpha} = \overline{S}_a + \alpha\left(\overline{S}_b - \overline{S}_a\right) = 0.3763$

$$\overline{S}_d^{\alpha} = \overline{S}_d + \left(\overline{S}_d - \overline{S}_c\right) = 0.2637$$

α - Level Fuzzy Midrange for α - Cut Fuzzy $\overline{\overline{X}}$ Control Chart Based on Standard Deviation

The control limits and centre line for α - Cut Fuzzy $\overline{\overline{X}}$ control chart based on standard deviation using α – Level fuzzy midrange are

$$UCL_{mr-\overline{X}}^{\alpha} = CL_{mr-\overline{X}}^{\alpha} + A_2 \left\{ \frac{\overline{S}_a^{\alpha} + \overline{S}_d^{\alpha}}{2} \right\} = 123.28$$

$$CL_{mr-\overline{X}}^{\alpha} = f_{mr-\overline{X}}^{\alpha}(CL) = \frac{\overline{\overline{X}}_a^{\alpha} + \overline{\overline{X}}_d^{\alpha}}{2} = 122.826$$

$$LCL_{mr-\overline{X}}^{\alpha} = CL_{mr-\overline{X}}^{\alpha} - A_2 \left\{ \frac{\overline{S}_a^{\alpha} + \overline{S}_d^{\alpha}}{2} \right\} = 122.37$$

The definition of α - level fuzzy midrange of sample j for fuzzy $\overline{\overline{X}}$ control chart is

$$S_{mr.\overline{X}j}^{\alpha} = \frac{\left(\overline{\overline{X}}_{aj} + \overline{\overline{X}}_{dj}\right) + \alpha\left|\left(\overline{\overline{X}}_{bj} - \overline{\overline{X}}_{aj}\right) - \left(\overline{\overline{X}}_{dj} - \overline{\overline{X}}_{cj}\right)\right|}{2}$$

Then, the condition of process control for each sample can be defined as:

Process control = {in control; for $LCL_{mr-\overline{X}}^{\alpha} \le S_{mr-\overline{X}j}^{\alpha} \le UCL_{mr-\overline{X}}^{\alpha}$

Out –of –control; otherwise}

VI. FUZZY $\overline{S}$ CONTROL CHART

The control limits for Shewhart $\overline{S}$ control chart is given by

$UCL_S = B_4\overline{S}, CL_S = \overline{S}$ and $LCL_s = B_3\overline{S}$ Where B_4 and B_3 are control chart co-efficient. Then the Fuzzy $\overline{S}$ control chart limits can be obtained as follows

$$UCL_s = B_4\overline{S} = B_4\left(\overline{S}_a, \overline{S}_b, \overline{S}_c, \overline{S}_d\right) \quad = (122.29, 122.27, 122.41, 122.44)$$

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$$=(0.896, 0.726, 0.561, 0.530)$$

$$CL_s = \overline{S} = \left(\overline{S}_a, \overline{S}_b, \overline{S}_c, \overline{S}_d\right)$$

$$=(0.426, 0.348, 0.269, 0.254)$$

$$LCL_s = B_3\overline{S} = B_3\left(\overline{S}_a, \overline{S}_b, \overline{S}_c, \overline{S}_d\right)$$

$$=0(0.426, 0.348, 0.269, 0.254) = (0000)$$

α - Cut Fuzzy Control Chart

The control limits of α - Cut Fuzzy $\overline{S}$ control chart can be obtained as follows:

$$UCL_s^\alpha = B_4\overline{S}^\alpha = B_4\left(\overline{S}_a^\alpha, \overline{S}_b, \overline{S}_c, \overline{S}_d^\alpha\right)$$

= 2.089(0.376, 0.348, 0.269, 0.2637)
= (0.785, 0.726, 0.561, 0.550)

$$CL_s^\alpha = \overline{S}^\alpha = \left(\overline{S}_a^\alpha, \overline{S}_b, \overline{S}_c, \overline{S}_d^\alpha\right)$$

= (0.376, 0.348, 0.269, 0.2637)

$$LCL_s^\alpha = B_3\overline{S}^\alpha = B_3\left(\overline{S}_a^\alpha, \overline{S}_b, \overline{S}_c, \overline{S}_d^\alpha\right) = (0, 0, 0, 0)$$

α - Level Fuzzy Midrange for α - Cut Fuzzy $\overline{S}$ Control Chart

The control limits of α - Level fuzzy midrange for α - Cut Fuzzy $\overline{S}$ control chart can be obtained in a similar way to α - Cut Fuzzy $\overline{R}$ control chart.

$$UCL_{mr-s}^\alpha = B_4 f_{mr-s}^\alpha\left(CL\right) = 2.089(0.32) = 0.668 \quad CL_{mr-s}^\alpha = f_{mr-s}^\alpha\left(CL\right) = \frac{\overline{S}_a^\alpha + \overline{S}_d^\alpha}{2} = 0.32$$

$$LCL_{mr-s}^\alpha = B_3 f_{mr-s}^\alpha\left(CL\right) = 0$$

The definition of α - level fuzzy midrange of sample j for fuzzy $\overline{S}$ control chart can be calculated as follows

$$S_{mr-s.j}^\alpha = \frac{\left(S_{aj} + S_{dj}\right) + \alpha\left|\left(S_{bj} - S_{aj}\right) - \left(S_{dj} - S_{cj}\right)\right|}{2}$$

Then, the condition of process control for each sample can be defined as:

Decision ={ in control; for $LCL_{mr-s}^\alpha \le S_{mr-s.j}^\alpha \le UCL_{mr-s}^\alpha$ Out –of –control; otherwise}

Table:4

Sample no	S^α_{mr-sj}	$0 \le S^\alpha_{mr-sj} \le 0.668$
1	0.353	In control
2	0.294	In control
3	0.293	In control
4	0.338	In control
5	0.323	In control
6	0.253	In control
7	0.354	In control

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8	0.262	In control
9	0.176	In control
10	0.282	In control

VII. RESULT AND CONCLUSION

From Table 4 it is found that the process is under control with respect to S^{α}_{mr-sj} for each sample. So these control limits can be used to control the production process. Since the plotted values are close to the control limits, Fuzzy control limits can provide more flexibility for controlling a process.Control charts have an efficient usage field to keep the process under control. In this investigation control chart and fuzzy logic are tried to combine. Construction of fuzzy control chart has some advantages and disadvantages. The major contribution of fuzzy set theory is its capability of representing vague data. With the help of the fuzzy set theory, flexibility of the system is improved. The main difficulty of constructing fuzzy control chart is selecting suitable membership function of linguistic variables. The assignment of membership function to each linguistic variable is not easy for process and quality engineers. The shape of membership function should be based on system behavior and user's preferences and also increasing and decreasing number of linguistic variables affect the performance of fuzzy control chart.

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