Comparison Between ($\overline{X}$ – R) Charts in Traditional and Deviation Nominal Methods with Usage Process Capability Analysis

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Abstract:-

Most companies aim to reduce costs by minimizing procedures, one of which is to reduce quality costs using statistical control. This research compares the application of the mean chart with range chart to control the quality of the output. The traditional method and the target dimension method were applied using the Minitab-17 program and Excel-13 program. Two properties have been studied applied to the lathe machine for gas cylinder neck product. After the statistical adjustment in the two methods, the ability of the face turning (0.69) and the external turning process for length (0.608) were estimated in both ways,and the process indicators were also studied. The target dimension chart can be used to group more than one product into a single chart.

Keywords: statistical control processes, control chart, target dimension method, process capability indicators.

1. Introduction

Statistical quality control is a powerful group of problem- solving tools which is useful in achieving process stability and improving capability through the reduction of variability [7]. One of the most commonly used statistical tools is Control charts introduced by Shewhart, no two products are exactly alike. This is so because the process that produces these products has many causes of variability [3]. The Control charts are effective tools for analysis of the variation of repetitive processes. In generic process, two different kinds of variations. Chance variations they are the noise of a production system and are uncontrollable variations. And another type assignable variations they can be properly identified and controlled [6].

2. Control Charts Principles

A control chart is widely used in industry as a graphical technique to monitor the output of the process in which statistics computed from measured values of a certain process characteristics are plotted versus time measurement,and two other horizontal lines, an upper line called the upper control limit (UCL), and a lower line for the lower control limit (LCL) [2].The upper and lower control limits are set at ∓3 standard deviation, are shown in the figure (1).

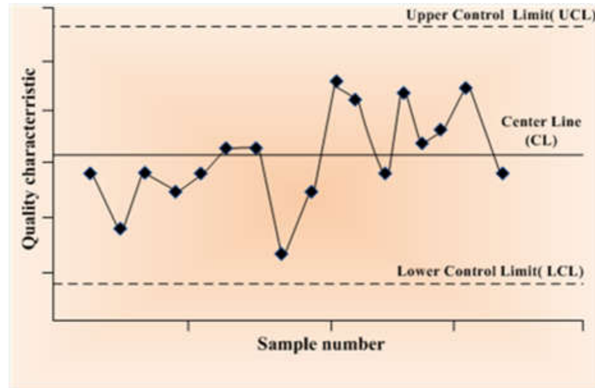

Fig .1 Quality Control Charts Structure [7]

In computing Xbar and range charts the most common control charts used in measuring continuous data. Special causes occurr that has changed the operating characteristics of the process. By identifying and eliminating these special causes [5].

Calculated subgroup average by applying the following equation [1].

$$\bar{X}_i = \sum_{j=1}^{n} X_{ij}/n \quad \text{.................} \; (1)$$

Calculate the grand average subgroups by applying the following equation [4].

$$\bar{\bar{X}} = \sum_{i=1}^{k} \bar{x}_i/k \quad \text{................} \; (2)$$

Thus, $\bar{\bar{X}}$ Would be used as the center line on a control chart.To construct the control limits, an estimate of the ranges of *m* samples [1].

$$R_i = Max(x_{i1}, \dots, x_{im}) - Min(x_{i1}, \dots, x_{im}) \quad \dots\dots\dots\dots\dots(3)$$

And the range average calculated from below equation [1]

$$\bar{R} = \frac{R_1 + R_2 + \cdots + R_k}{k} \quad \dots\dots\dots\dots\dots(4)$$

Calculate the trail control limit for $\bar{x}$ Chart by applying the following equations [7]:

$$UCL_{\bar{X}} = \bar{\bar{X}} + A_2 \bar{R} \quad \dots\dots\dots\dots\dots(5)$$

$$\text{Center line} = \bar{\bar{X}} \quad \dots\dots\dots\dots\dots(6)$$

$$LCL_{\bar{X}} = \bar{\bar{X}} - A_2 \bar{R} \quad \dots\dots\dots\dots\dots(7)$$

Where:

$UCL_{\bar{X}}$ = upper control limits for X bar chart.

$LCL_{\bar{X}}$ = lower control limit for X bar chart.

A_2 = Constant can be from table (1) for Subgroup (m) size.

Calculate the trail control limit for $\bar{R}$ Chart by applying the equations [7]:

$$UCL_{\bar{R}} = D_4 \bar{R} \quad \dots\dots\dots\dots\dots(8)$$

D_4,D_3 = Constant can be from the table (1).

An estimate of the inherent common cause's standard deviation may be calculated as follows [1].

$$\hat{\sigma} = \bar{R}/d_2 \quad \dots\dots\dots\dots\dots(10)$$

Where:

$\hat{\sigma}$ = Estimated common cause standard deviation of the process.

$\bar{R}$ = Average of the k subgroup ranges.

d_2 = Constant can be from table (1) for Subgroup (m) size.

Table .1 Coefficients for Control Charts for Variables [7]

X-bar Chart Constants			For Sigma estimated	R-Chart Constants	
Sample Size =m	A_2	A_3	d_2	D_3	D_4
2	1.88	2.659	1.128	0	3.267
3	1.023	1.954	1.693	0	2.575
4	0.729	1.628	2.059	0	2.282
5	0.577	1.427	2.326	0	2.115

3. Short Run Control Chart

Mass production lot sizes are generally large and constructing a control chart is not difficult. Now day's trend manufacturing is to produce small lot sizes or use short production run for flexible manufacturing using job shop system. Therefore some modification to conventional control charts. Cullene and Both introduced a control chart called the Deviation from the Nominal Method (DNOM) can be expressed by the following equation that apply and called target dimension chart[4].

$$X_i = M_i - T_A \qquad \text{……………(11)}$$

Where:

X_i= Number of Deviation from Nominal

M_i=The actual sample measurement

T_A= Target value of Process

4. Process capability Analysis

In the field of quality control, process capability is used to compare the output of a process to the specification limits of the product to be produced .Process capability index (PCI) is widely used to measure the inherent variability of a process and thus reflect its performance [8].

The common PCI including Cp, Cpk, Cpu, Cpl and Cpm are widely used in practice, they can expressed by the following equations [9].

$$Cp = \frac{USL-LSL}{6\sigma} \qquad \text{……………(12)}$$

Where:

USL=Upper Specification Limit

LSL=lower Specification Limit

σ = Standard Deviation can get from $\bar{R}/d_2$.

$\hat{\sigma}$ = Estimated common cause standard deviation of the process.

$\bar{R}$ = Average of the k subgroup ranges.

d_2 = Constant can be from table (1) for Subgroup (m) size.

$$Cpu = \frac{USL-\mu}{6\sigma} \quad \ldots\ldots\ldots\ldots\ldots(13)$$

$$Cpl = \frac{\mu-LSL}{6\sigma} \quad \ldots\ldots\ldots\ldots\ldots(14)$$

$$Cpk = \frac{\min(USL-\mu, LSL-\mu)}{3\sigma} \ldots\ldots\ldots\ldots(15)$$

Where :

μ = Process mean

$$Cpm = \frac{USL-LSL}{6\sqrt{\sigma^2+(\mu-T)^2}} \ldots\ldots\ldots\ldots\ldots(16)$$

5. Practical Application

To cover the market need and produce competitive products for international products.Figure (2) shows the gas cylinder neck sample. This part is produced on turning machine.

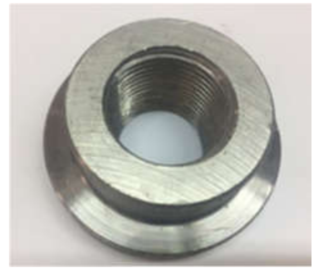

Fig.2 Gas Cylinder Neck Sample

The Dimensions and tolerances of the raw material for gas cylinder neck steel (37-2) which is shown in figure (3-a), all these dimensions are in millimeter unit.

Manufacturing Stagesfor Collect Data:

Stage One: Face Turning Process

After cutting work piece length reduces from (28mm) to (26^{+0}_{-1} mm) by face turning shown in figure (3-b).

Stage Two: External Turning Process

At this stage, achieve length dimension (16^{+0}_{-1}mm), , figure (3-c) shown the final dimension these processes.

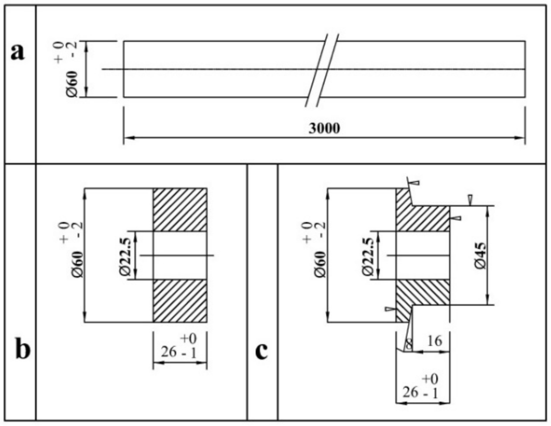

Fig .3 Technical Path of Manufacturing [10]

Data collecting for the two process shown in the table (2) and (3) . Summary of statistics calculating are illustrated in table (4) constructed by using Minitab -17 software. Figures (4) and (5) show that process in control state. Table (5) and (6) convert data by using Microsoft Excel- 2013 to the short run method. Table (7) shows summary calculations for data in a short run method, figures (6) and (7) for the DNOM method. Equations (12), (13), (14), (15) and (16) are applied to find PCI as explain in table (8).

Table.2 Data for Face Turning Characteristic to Length

S.N	Readings (mm)				
	X_1	X_2	X_3	X_4	X_5
1	25.90	25.10	25.98	26	25.55
2	25.96	25.99	25.84	25.61	25.60
3	25.55	25.88	25.27	25.52	25.41
4	25.40	25.79	25.18	25.90	25.64
5	25.90	25.88	25.52	25.76	25.86
6	25.61	25.13	25.87	25.94	25.03
7	25.57	25.65	25.79	25.57	25.81
8	25.59	25.50	25.94	25.31	25.43
9	25.61	25.45	25.67	25.81	25.62
10	25.73	25.94	25.42	25.70	25.91
11	25.64	25.86	25.21	25.71	25.29
12	25.97	25.79	25.69	25.74	25.92
13	25.69	25.50	25.69	25.69	25.90
14	25.56	25.39	25.87	25.48	25.47
15	25.75	25.65	25.55	25.69	25.16
16	25.84	25.30	25.73	25.45	25.33
17	25.18	25.10	25.61	25.71	25.47
18	25.30	25.94	25.73	25.89	25.62
19	25.10	25.65	25.69	25.68	25.91
20	25.73	25.23	25.64	25.65	25.67
21	25.41	25.73	25.69	25.21	25.87
22	25.43	25.86	25.73	25.66	25.67
23	25.29	25.62	25.87	25.75	25.45
24	25.94	25.29	25.45	25.76	25.13
25	25.88	25.90	25.50	25.73	25.66

Table .3 Collection Data for External Machining Characteristic by Length

S.N	Readings (mm)				
	X_1	X_2	X_3	X_4	X_5
1	15.88	15.49	15.29	15.70	15.84
2	16	15.9	15.80	15.71	15.98
3	15.75	15.69	15.68	15.95	15.98

4	15.9	15.54	15.55	15.88	16
5	15.76	16	15.63	15.65	16.02
6	15.82	16.05	15.22	15.48	16.01
7	15.94	15.7	15.64	15.67	15.99
2	16	15.9	15.80	15.71	15.98
3	15.75	15.69	15.68	15.95	15.98
4	15.9	15.54	15.55	15.88	16
5	15.76	16	15.63	15.65	16.02
6	15.82	16.05	15.22	15.48	16.01
7	15.94	15.7	15.64	15.67	15.99
8	15.66	15.44	15.99	15.96	15.97
9	15.74	15.32	15.67	15.22	15.32
10	15.59	15.88	15.48	15.67	15.47
11	15.61	16	15.96	15.24	15.97
12	15.87	15.97	15.18	15.98	15.23
13	15.56	16.05	15.66	15.47	15.56
14	15.19	15.97	15.76	15.66	15.68
15	15.62	15.66	15.84	15.25	15.78
16	15.77	15.74	15.99	15.97	15.12

Table .4 Summary of Results for Calculations ($\overline{X}$ and R) Values

S.N	Face Turning to Length		External Turning to Length	
	$\overline{X}$	R	$\overline{X}$	R
1	25.706	0.9	15.64	0.59
2	25.8	0.39	15.878	0.29
3	25.526	0.61	15.81	0.3
4	25.582	0.72	15.774	0.46
5	25.784	0.38	15.812	0.39
6	25.516	0.91	15.716	0.83
7	25.678	0.24	15.788	0.35
8	25.554	0.63	15.804	0.55
9	25.632	0.36	15.46	0.52
10	25.74	0.52	15.618	0.41
11	25.542	0.65	15.756	0.76
12	25.822	0.28	15.646	0.8
13	25.694	0.4	15.66	0.58
14	25.554	0.48	15.652	0.78
15	25.56	0.59	15.63	0.59
16	25.53	0.54	15.718	0.87
17	25.414	0.61	15.42	0.75
18	25.696	0.64	15.354	0.67
19	25.606	0.81	15.4	0.89
20	25.548	0.5	15.362	0.91
21	25.582	0.66	15.674	0.92
22	25.67	0.43	15.618	0.93
23	25.596	0.58	15.65	0.64
24	25.514	0.81	15.368	0.63
25	25.734	0.4	15.55	0.53
	$\overline{\overline{X}}$	$\overline{R}$	$\overline{\overline{X}}$	$\overline{R}$
	25.6246	0.5616	15.6301	0.6376
	$\hat{\sigma}_{Xbar-R}$		$\hat{\sigma}_{Xbar-R}$	
	0.241445		0.27411	

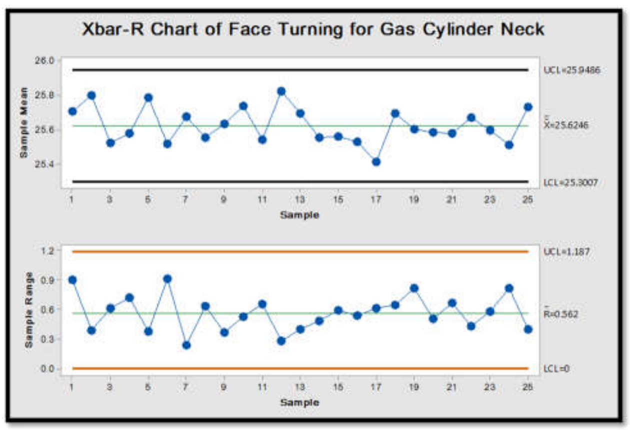

Figure .4 Xbar-R chart Approved for Face Turning

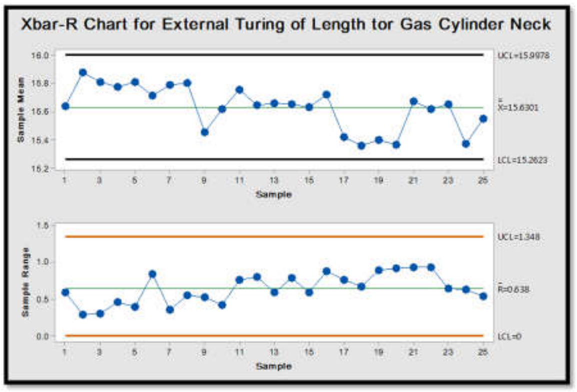

Figure .5 Xbar-R chart Approved for External Turning of Length

Table.5 DNOM for Face Turing Process

S.N	Readings (mm)				
	X_1	X_2	X_3	X_4	X_5
1	-0.1	-0.9	-0.02	0	-0.45
2	-0.04	-0.01	-0.16	-0.39	-0.4
3	-0.45	-0.12	-0.73	-0.84	-0.59
4	-0.6	-0.21	-0.82	-0.1	-0.36
5	-0.1	-0.12	-0.48	-0.24	-0.14
6	-0.39	-0.87	-0.13	-0.06	-0.97
7	-0.43	-0.35	-0.21	-0.43	-0.19
8	-0.41	-0.5	-0.06	-0.69	-0.57
9	-0.39	-0.55	-0.33	-0.19	-0.38
10	-0.27	-0.06	-0.58	-0.3	-0.09
11	-0.36	-0.14	-0.79	-0.29	-0.71
12	-0.03	-0.21	-0.31	-0.26	-0.08
13	-0.31	-0.5	-0.31	-0.31	-0.1
14	-0.44	-0.61	-0.13	-0.52	-0.53
15	-0.25	-0.35	-0.45	-0.31	-0.84
16	-0.16	-0.7	-0.27	-0.55	-0.67
17	-0.82	-0.9	-0.39	-0.29	-0.53
18	-0.7	-0.06	-0.27	-0.11	-0.38
19	-0.9	-0.35	-0.31	-0.32	-0.09
20	-0.27	-0.77	-0.36	-0.35	-0.33
21	-0.59	-0.27	-0.31	-0.79	-0.13
22	-0.57	-0.14	-0.27	-0.34	-0.33
23	-0.71	-0.38	-0.13	-0.25	-0.55
24	-0.06	-0.71	-0.55	-0.24	-0.87
25	-0.12	-0.1	-0.5	-0.27	-0.34

Table.6 DNOM for External Turning to Length Process

S.N	Readings (mm)				
	X_1	X_2	X_3	X_4	X_5
1	-0.12	-0.51	-0.71	-0.3	-0.16
2	0	-0.1	-0.2	-0.29	-0.02
3	-0.25	-0.31	-0.32	-0.05	-0.02
4	-0.1	-0.46	-0.45	-0.12	0
5	-0.24	0	-0.37	-0.35	0.02
6	-0.18	0.05	-0.78	-0.52	0.01
7	-0.06	-0.3	-0.36	-0.33	-0.01
8	-0.34	-0.56	-0.01	-0.04	-0.03
9	-0.26	-0.68	-0.33	-0.78	-0.68
10	-0.41	-0.12	-0.52	-0.33	-0.53
11	-0.39	0	-0.04	-0.76	-0.03
12	-0.13	-0.03	-0.82	-0.02	-0.77
13	-0.44	0.05	-0.34	-0.53	-0.44
14	-0.81	-0.03	-0.24	-0.34	-0.32
15	-0.38	-0.34	-0.16	-0.75	-0.22
16	-0.23	-0.26	-0.01	-0.03	-0.88
17	-0.34	-0.77	-0.24	-0.56	-0.99
18	-0.59	-0.67	-0.33	-0.64	-1
19	0	-0.35	-0.88	-0.88	-0.89
20	-0.93	-0.58	-0.82	-0.02	-0.84
21	-0.02	-0.13	-0.92	-0.56	0
22	-0.05	-0.36	-0.3	-0.22	-0.98
23	-0.31	-0.13	-0.29	-0.25	-0.77
24	-0.46	-0.48	-0.97	-0.34	-0.91
25	-0.33	-0.45	-0.24	-0.46	-0.77

Table.7 Summary of Results Short Run Method

Subgroup No.	Face Turning to Length (SR)		External Turning to Length (SR)	
	$\overline{X}$	R	$\overline{X}$	R
1	-0.294	0.9	-0.36	0.59
2	-0.2	0.39	-0.122	0.29
3	-0.474	0.61	-0.19	0.3
4	-0.418	0.72	-0.226	0.46
5	-0.216	0.38	-0.188	0.39
6	-0.484	0.91	-0.284	0.83
7	-0.322	0.24	-0.212	0.35
8	-0.446	0.63	-0.196	0.55
9	-0.368	0.36	-0.546	0.52
10	-0.26	0.52	-0.382	0.41
11	-0.458	0.65	-0.244	0.76
12	-0.178	0.28	-0.354	0.8
13	-0.306	0.4	-0.34	0.58
14	-0.446	0.48	-0.348	0.78
15	-0.44	0.59	-0.37	0.59
16	-0.47	0.54	-0.282	0.87
17	-0.586	0.61	-0.58	0.75
18	-0.304	0.64	-0.646	0.67
19	-0.394	0.81	-0.6	0.89
20	-0.416	0.5	-0.638	0.91
21	-0.418	0.66	-0.326	0.92
22	-0.33	0.43	-0.382	0.93
23	-0.404	0.58	-0.35	0.64
24	-0.486	0.81	-0.632	0.63
25	-0.266	0.4	-0.45	0.53
	$\overline{\overline{X}}$	$\overline{R}$	$\overline{\overline{X}}$	$\overline{R}$
	-0.37536	0.5616	-0.36992	0.6376
	$\hat{\sigma}_{Xbar-R}$		$\hat{\sigma}_{Xbar-R}$	
	0.241445		0.274119	

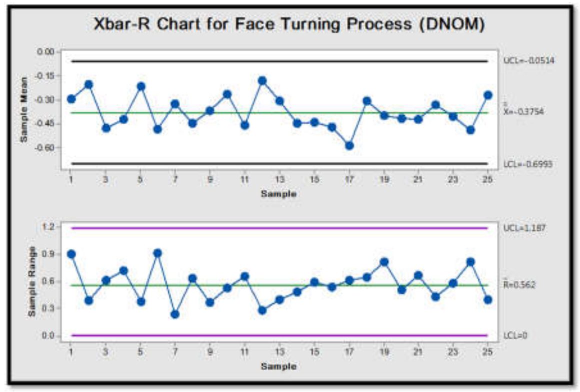

Figure.6 Xbar-R_{SR} Chart Approved for Face Turning Process

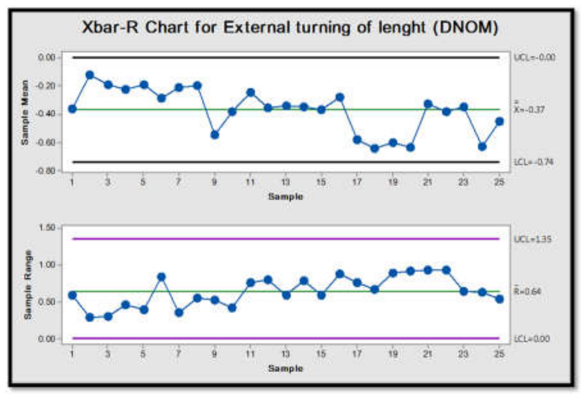

Figure.7 Xbar-R_{SR} Chart Approved for External Turning of Length Process

Table .8 Summary Result of PCI

Indicator	Method			
	Traditional		Short Run	
	Face Turning	External Turning to Length	Face Turning	External Turning to Length
Cp	0.69	0.608	0.69	0.608
C_{Pk}	0.518	0.449	0.518	0.449
C_{Pu}	0.862	0.766	0.862	0.766
C_{Pl}	0.518	0.449	0.518	0.449

C_{Pm}	0.373	0.361	0.373	0.361

6. Results and Discussion

6.1 (Traditional Method)

6.1.1 Face Turning process

From table (4) shown approved control limit result for characteristics under study the following notice:

1. The calculated dimension ($\bar{\bar{X}}$) decrease from the target dimension (X_T) by 0.3754 .
2. In both charts the control limit inside the specification limit this good in statistically.
3. The difference between $UCL_{\bar{X}}$ and USL equal to (0.12 σ) where σ equals 0.241445, and the different $LCL_{\bar{X}}$ and LSL equal (1.24σ).

From the result of PCI in the table (8) we can notice:

1. The value of Cp equals 0.69 which gives an indication that process, not capable because the process dispersion is outside the range specified.
2. The value of Cpk equals 0.518 indicating the process means not centered and shifted toward the upper specific limit because Cpk<Cp
3. The Cpm value equals 0.373 this mean Cpm<Cp that the process mean is shifted away from the target value.

6.1.2 External Turning to Length Process

From table (4) shown approved control limit result for characteristics under study the following notice:

1. The calculated dimension ($\bar{\bar{X}}$) decreases from the target dimension (X_T) by 0.3699 .
2. The control limit inside the specification limit this good in the statisticly.
3. The difference between $UCL_{\bar{X}}$ and USL equal to (0.008 σ) wher σ = 0.27411, and the different $LCL_{\bar{X}}$ and LSL equal (0.95σ).

From the result of PCI in the table (8) we can notice:

4. The value of the Cp=0.608 which gives an indication that process, not capable because the process dispersion is outside the range specified..

1. The value of Cpk =0.449 this means the process mean not equal target value and shifted toward the upper specification limit because Cpk<Cp.
2. The value Cpm <Cp this mean there is a shift in the process mean away from the target value.

6.2 (Short Run Method)

From table (7) shown results for calculation of approved control limit, though data are treated in a short run manner and apply control charts show :

1. All operations were the average mean shift towards the lower specification limits this appears too in the table (4) and about the same amount of deviation .
2. The mean range and mean deviation were identical with traditional and short run methods.
3. Table (8) show summary Result for process capability index in Short Run method is the same magnitude for PCI with traditional method

7. Conclusion

1. Minimizing the number of control chart by use (DNOM) method, which collect properties of the group in one chart lead to reducing costs compared with traditional method.
2. The Cp value of two processes under study was less than one, is mean not a capable process to achieve specifications limit and need more control to reduce parts defect.

3. The value of Cpk and Cpm for two processes smaller than one too, is mean it need to re-install the machine from time to time, resulting reducing dispersion shifted from process mean to be closer to target value.

4. The target dimension charts (DNOM) can be employed as an alternative to traditional.

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Symbols	Description
A_2	constant for converting the average range to three standard errors for the X-bar chart
d_2	constant for converting the average range to an estimate of sigma
D_3, D_4	constants for converting the average range to three sigma limit for the R chart see in
k	Number of subgroup used in calculation of control limit
n	Subgroup size , number of observations in a subgroup
R_i	Range of the observation in the *i*th subgroup for the R chart
$\bar{R}$	Average of the *k* subgroup ranges
T	Process target value of the process mean
X	Reading Value
$\bar{X}_i$	Average of the *i*th subgroup observations for the x-bar chart
$\bar{\bar{X}}$	Average of the *k* subgroup averages for the x-bar chart
Cp	Process Capability Index , used when USL and LSL are Relevant
Cpk	Process Capability Index , used when USL and LSL are Relevant
Cpu	Process Capability Index , Used When USL and μ are Relevant
Cpl	Process Capability Index , Used When LSL and μ are Relevant
Cpm	Process Capability Index , Used ,when μ and *T* are Relevant
σ	Standard Deviation
$\hat{\sigma}$	Estimated common cause standard deviation of the process
6σ	Process spread
μ	Process Mean
σ^2	Process Variance

مقارنة بين لوحة المتوسط والمدى بالطريقة التقليدية وطريقة البعد المستهدف باستخدام تحليل مقدرة العملية

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الخلاصة:-

أغلب الشركات تهدف الى تقليل الكلف من خلال تقليل الاجراءات ,وأحد هذه الاجراءات يتمثل بتقليل تكاليف النوعية باستخدام السيطرة الاحصائية . البحث يقارن تطبيق لوحة المتوسط والمدى للسيطرة على النوعية الانتاج . طبقت الطريقة التقليدية وطريقة البعد المستهدف باستخدام برنامج الميناتاب -17 وبرنامج الاكسل-13 . خاصيتين تمت دراستهما مطبقة على ماكنة الخراطة لمنتج عنق اسطوانة الغاز . بعد الضبط الاحصائي بالطريقتين كانت مقدرة عملية الخراطة الوجهية (0.69) وعملية الخراطة الخارجية بالنسبة للطول (0.608) بالطريقتين ومؤشرات مقدرة العملية درست ايضا". يمكن استخدام لوحة البعد المستهدف في تجميع اكثر من خاصية لمنتج بلوحة واحدة.

كلمات البحث: عمليات السيطرة الاحصائية , مخططات السيطرة ,طريقة البعد المستهدف, مؤشرات مقدرة العملية .