Capability process on Shewhart p control chart and ISRT p EWMA control chart on shift drum production

by Wahyukaton Ramdani

Submission date: 15-Mar-2021 07:38PM (UTC-0700)
Submission ID: 1534177609
File name: 13th_ISIEM_2021_paper_79.pdf (311.46K)
Word count: 2944
Character count: 12525

Capability process on Shewhart *p* control chart and ISRT *p* EWMA control chart on shift drum production

Wahyukaton[(1)], **Ramdani Herman**[(2)]
[(1)(2)]Industrial Engineering Department, Engineering Faculty, Universitas Pasundan
Jl. Setiabudi 193 Bandung, West Java, Indonesia.
[(1)]wahyukaton@unpas.ac.id, [(2)]ramdaniherman.rh@gmail.com

Abstract. The common often used control chart on the quality control process is Shewhart Control Chart. However, the Shewhart Control Chart seems to be less sensitive in small shifting on process control. The ISRT *p* EWMA Control Chart is proposed to detecting a small shifting, which can be used on the condition for the value of $np \geq 5$. The data have been processed and calculated using the Shewhart *p* control chart and the ISRT *p* EWMA Control Chart using defects on shift drums. When the process has been controlled, then start to calculate the capability process for each control chart. There are two parameters on the ISRT *p* EWMA Control Chart, which are λ and L, and the weighted value was given will significantly affect shift detection. From the calculation, it was known that the ISRT *p* EWMA Control Chart was better at detecting out-of-control data. The smaller parameter value is given, then the ISRT *p* EWMA Control Chart was more sensitive on shifting detection, and the smaller parameter value, then the capability process will decrease. The parameter value of λ is 0.20 and $L = 2.962$ is the lowest value to find the capability process larger than 1.00.
Keywords: Shewhart Control Chart, ISRT *p* EWMA Control Chart, shifting, capability process

1. Introduction

Statistical Process Control (SPC) is a very useful technique for analyzing a quality problem and improving production process performance. It is a powerful collection of problem-solving tools to achieve the process's stability and a capability improvement for variability reduction. [1]

There are two types of control chart, variable control chart ($\bar{X} - R$, and $\bar{X} - S$) and attribute control chart (p, np, c, u). The other control chart is the Exponentially Weighted Moving Average (EWMA) chart is an alternative control chart to detect a small shifting. The EWMA Control Chart is adequate to detect a small shift in the mean process. EWMA parameter design is a multiplication of sigma (σ) which is used in control limit (L) and lambda (λ) value. With a normal approximation for the binomial distribution, EWMA is not suitable for the large sample size or $np \geq 5$. [6]

The shift drum manufacturer was determined to control the process, and an attribute control chart was used to monitoring the number of defects. However, due to a 100% inspection, a large sample size resulted in many false alarms to detect a small shift.

Tsai, T-R. et al. proposed Improved Square Root Transformation (ISRT) for binomial distribution to be applied on the *p* control chart. ISRT can overcome a small value of *p* for the small sample size to larger sample size [3]. A modified EWMA Control Chart was proposed based on the ISRT method to detect a shifting in a binomial distribution, and the ISRT *p* EWMA control chart can be used on the value of $np \geq 5$.[6]

This research's objectives are applying the ISRT p EWMA control chart on producing the shift drums, analyzing process capability for defects using Shewhart p control chart, and using the ISRT p EWMA control chart.

2. Method

Shewhart proposed a control chart's statistical principles for fractions of nonconforming based on the binomial distribution. If the production process has already been stable, the probability of nonconforming to a specification is p. If a random sample on n units of a product is selected, and D is the number of nonconforming units of product, then D is a binomial distribution with parameters n and p,

$$P\{D = x\} = \binom{n}{x} p^x(1-p)^{n-2}; x = 0,1,2,\dots,n \quad (1)$$

While $\hat{p} = \frac{D}{n}$, and $\mu_{\hat{p}} = p$, and $\sigma_{\hat{p}} = \sqrt{\frac{p(1-p)}{n}}$ .... (2)

So that, when p is the true fraction of nonconforming in the production process, then the center line and control limits are as follow,

$$UCL = p + 3\sqrt{\frac{p(1-p)}{n}};\ \text{Center line} = p;\ LCL = p - 3\sqrt{\frac{p(1-p)}{n}} \quad (3)$$

EWMA control chart is an alternative control chart for the Shewhart control chart for a small shifting leading to the defectives. There are two parameters, [1]

1. λ is the first weight given to the data, and its value is between 0 to 1. Some recommendations from previous research, the λ value is $0.05 \leq \lambda \leq 0.25$ or $0.2 \leq \lambda \leq 0.3$
2. L is a multiplication of rational subgroups of standard deviation used on the construction of the control limit so that the L value is usually 3. When the λ value is low, the L value must be decreased as well.

The first step on the construction of the EWMA control chart is, [2]

$$Z_i = \lambda p_i + (1-\lambda)Z_{1-i} \quad (4)$$

Where $0 \leq \lambda \leq 1$ is constant and initial value (first sample at i = 1) is process target, so $Z_0 = \mu$, and for some cases, the initial value of EWMA is the mean, so that $Z_0 = \bar{p}$.

To show that EWMA is weighted mean from all sample mean, Z_{i-1} can be replaced by Z_i to find

$$Z_i = \lambda p_i + (1-\lambda)[\lambda p_{i-1} + (1-\lambda)Z_{i-2}]$$
$$= \lambda p_i + \lambda(1-\lambda)p_{i-1} + (1-\lambda)^2 Z_{i-2} \quad (5)$$

To Simplify i = 2, 3, 4, …, Z_i can be stated as

$$Z_i = \lambda\sum_{j=0}^{i-1}(1-\lambda)^j p_{i-j)} + (1-\lambda)^i Z_0 \quad (6)$$

The weight of $\lambda(1-\lambda)^j$ is geometrically decreased by the sample mean so that the weight will become,

$$\lambda\sum_{j=0}^{i-1}(1-\lambda)^j = \lambda\left[\frac{1-(1-\lambda)^i}{1-(1-\lambda)}\right] = 1-(1-\lambda)^i \quad (7)$$

The EWMA control limits are,

$$UCL = p + k\sqrt{\frac{pq}{n}\frac{\lambda}{2-\lambda} - (1-(1-\lambda)^{2i})}$$

$$UCL = p + k\sqrt{\frac{pq}{n}\frac{\lambda}{2-\lambda}} \quad (8)$$

and

$$LCL = p - k\sqrt{\frac{pq}{n}\frac{\lambda}{2-\lambda} - (1-(1-\lambda)^{2i})}$$

$$LCL = p - k\sqrt{\frac{pq}{n}\frac{\lambda}{2-\lambda}} \quad (9)$$

When p is small and n small, the sample size is not adequate to normal distribution. An ISRT p control chart has been used. The control limits are,

$$UCL_p = \sqrt{p} + \frac{3}{2}\sqrt{\frac{1-p}{n}} - \frac{1}{2}\left(\frac{1-p}{n\sqrt{p}}\right)$$

Center line = $CL_p = \sqrt{p}$

$$LCL_p = \sqrt{p} - \frac{3}{2}\sqrt{\frac{1-p}{n}} - \frac{1}{2}\left(\frac{1-p}{n\sqrt{p}}\right) \quad \ldots\ldots \quad (10)$$

These control limits are in low defect, $p \leq 0.1$. If the parameter p is unknown, it can be estimated by,

$$\bar{p} = \frac{\sum_{i=1}^{m} D_i}{mn} = \frac{\sum_{i=1}^{m} \hat{p}_i}{m} \quad \ldots\ldots \quad (11)$$

Where D = defect item in sample i, and m = initial sample size n

Sukparungse proposed shift detection in a binomial distribution, an Improved square Root Transformation (ISRT) can be applied to three control charts: p, np, and c. [2][6][4]

The upper control limit is,

$E(X) = \sqrt{P}$; and

$$V(X) = \left[\frac{1}{2}\sqrt{\frac{1-p}{n}} - \frac{1}{6}\left(\frac{1-p}{n\sqrt{p}}\right)\right]^2 \quad \ldots\ldots \quad (12)$$

The lower control limit is,

$E(X) = \sqrt{P}$; and

$$V(X) = \left[\frac{1}{2}\sqrt{\frac{1-p}{n}} - \frac{3}{8}\left(\frac{1-p}{n\sqrt{p}}\right)\right]^2 \quad \ldots\ldots \quad (13)$$

So that, the modified the ISRT p EWMA Control Chart is,

$$UCL_{ISRTEWMA} = \sqrt{p} + L\sqrt{\frac{\lambda}{2-\lambda}\left[\frac{1}{2}\sqrt{\frac{1-p}{n}} - \frac{1}{6}\left(\frac{1-p}{n\sqrt{p}}\right)\right]} \quad \ldots\ldots \quad (14)$$

and

$$LCL_{ISRTEWMA} = \sqrt{p} - L\sqrt{\frac{\lambda}{2-\lambda}\left[\frac{1}{2}\sqrt{\frac{1-p}{n}} - \frac{3}{8}\left(\frac{1-p}{n\sqrt{p}}\right)\right]} \quad \ldots\ldots \quad (15)$$

With L is the ISRT p EWMA Control Chart coefficient.[3]

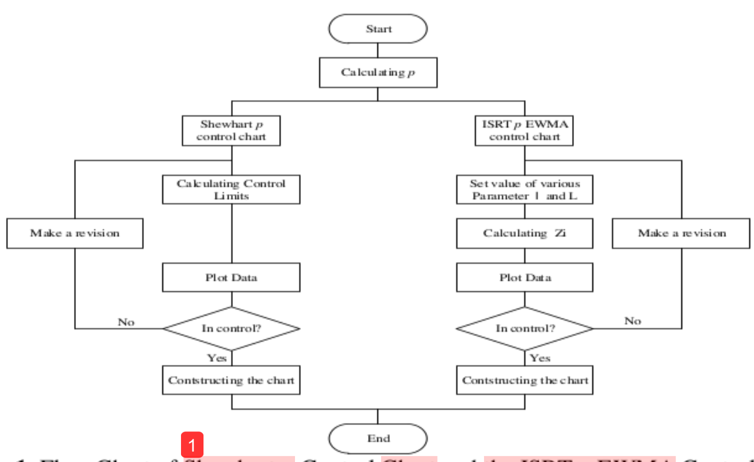

Figure 1. Flow Chart of Shewhart p Control Chart and the ISRT p EWMA Control Chart

The capability process can be determined as, [1]

$$\bar{p} \approx \mu = \frac{\sum pi}{\sum n} \quad (16)$$

Then, determine the σ value as,

$$\sigma = \sqrt{\frac{\bar{p}\ x\ (1-\bar{p})}{\sum n}} \quad (17)$$

Calculating Capability Potential (C_p) as

$$C_p = \frac{USL-LSL}{6\sigma} \quad (18)$$

Calculating upper specification and lower specification as

$$C_{pu} = \frac{USL-\mu}{3\sigma} \text{ and } C_{pl} = \frac{\mu-LSL}{3\sigma} \quad (19)$$

Calculating Capability Index (C_{pk})

$$C_{pk} = \min(C_{pu}; C_{pl}) \quad (20)$$

The number of shift drum been produced on January 2019 to March 2020 were 13,902 units. There are four defect types, A. Chips defect, B. Dirty defect, C. Notch defect, and D. Slit defect, as shown in figure 2.

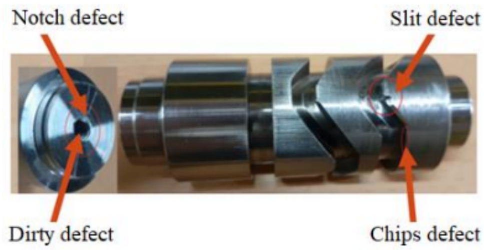

Figure 2. Defects Classification

3. Result and Discussion

3.1 Constructing the Shewhart p *Control Charts and the Capability Processes*

After completing all calculation for constructing the Shewhart *p* Control Chart for all defect types using equations no (2) and (3), the charts are as follow,

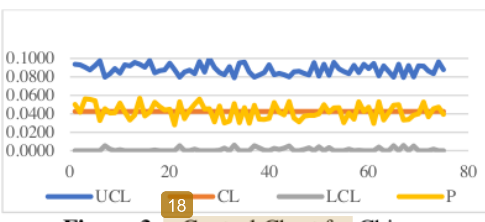

Figure 3. p Control Chart for Chips

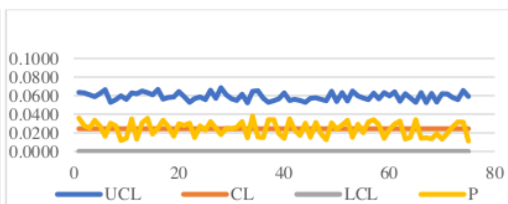

Figure 4. p Control Chart for Dirty

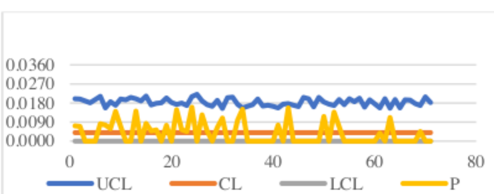

Figure 5. p Control Chart for Notch

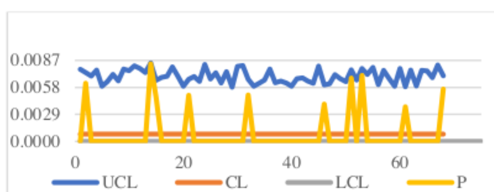

Figure 6. p Control Chart for Slit

Then the capability process for each defect types was calculated using equations no (16) to (20) are as follow,

Table 1. Capability Process for Defect Types on *Shewhart* p

Defect Types	LSL	USL	μ	σ	C_p	C_{pu}	C_{pl}	C_{pk}
Chips	0,0011	0,0880	0,0425	0,0017	8,46	8,86	8,07	8,07
Dirty	0,0000	0,0591	0,0244	0,0013	7,54	8,86	6,21	6,21
Notch	0,0000	0,0184	0,0040	0,0006	5,51	8,61	2,41	2,41
Slit	0,0000	0,0070	0,0008	0,0002	4,74	8,42	1,05	1,05

From Table 1, it was obvious that C_p value for all defect types is larger than 1.33, which means that the capability process is in good value. Also, the table shows that C_{pk} value for all defect types is larger than 1.0, which means that no action is needed since they are in a good value.

3.2 Constructing the ISRT p *EWMA Control Charts and the Capability Processes*

Several calculations were conducted using equations no (4) to (15) to constructing control charts for all defect types, and there were out-of-control conditions, and there were special causes found only for defect type Slit. The revisions were conducted for defect type Chips, Dirty, and Notch, while defect type Slit cannot be revised due to there were special causes found, and the process has to be stopped to conducting a full inspection on machine setup and machine configuration. However, defect type Slit is still included in the constructing ISRT *p* EWMA Control Charts.

The various parameters were applied to construct ISRT *p* EWMA Control Charts, [2] which were, $\lambda = 0.40$; $L = 3.054$, $\lambda = 0.25$; $L = 2.998$, $\lambda = 0.20$; $L = 2.962$, $\lambda = 0.10$; $L = 2.814$, $\lambda = 0.05$; $L = 2.615$.

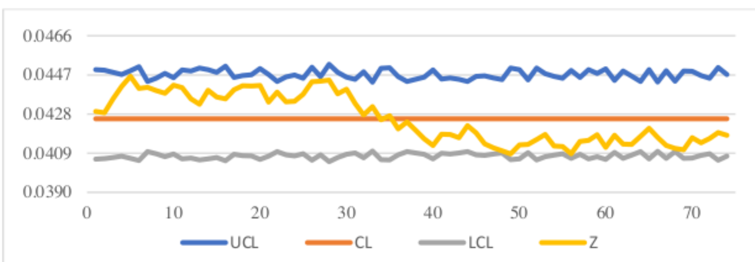

Figure 7. Controlled Chart for Chips ($\lambda = 0.05$; $L = 2.615$)

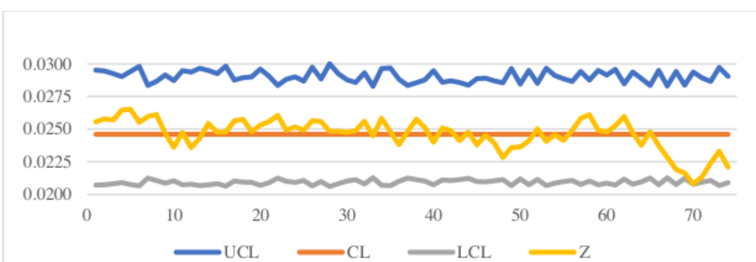

Figure 8. Controlled Chart for Dirty ($\lambda = 0.10$; $L = 2.814$)

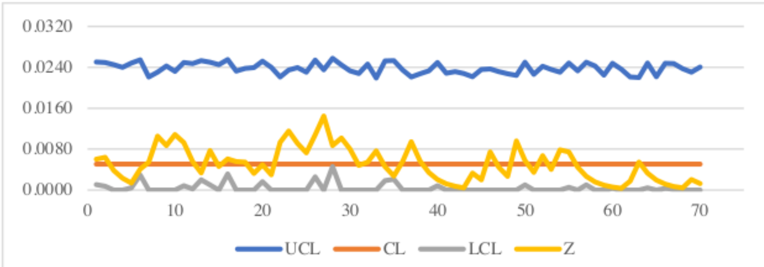

Figure 9. Controlled Chart for Notch ($\lambda = 0.40$; $L = 3.054$)

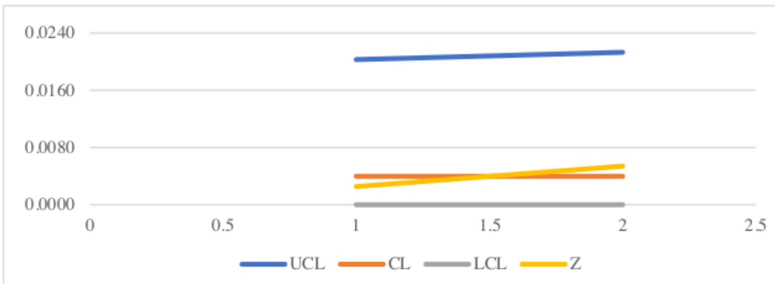

Figure 10. Controlled Chart for Slit ($\lambda = 0.40$; $L = 3.054$)

Then the capability process for each defect types was calculated using equations no (16) to (20) are as follow,

Table 2. Capability Process for Defect Types on the ISRT p EWMA

Defect Type	Parameters	LSL	USL	μ	σ	C_p	C_{pu}	C_{pl}	C_{pk}
Chips	$\lambda = 0.40$; $L = 3.054$	0.0221	0.0672	0.0425	0.0017	4.39	4.81	3.98	3.98
	$\lambda = 0.25$; $L = 2.998$	0.0310	0.0564	0.0425	0.0017	2.47	2.70	2.23	2.23
	$\lambda = 0.20$; $L = 2.962$	0.0337	0.0531	0.0425	0.0017	1.89	2.07	1.72	1.72
	$\lambda = 0.10$; $L = 2.814$	0.0385	0.0473	0.0425	0.0017	0.85	0.93	0.77	0.77
	$\lambda = 0.05$; $L = 2.615$	0.0408	0.0447	0.0426	0.0017	0.38	0.42	0.35	0.35
Dirty	$\lambda = 0.40$; $L = 3.054$	0.0063	0.0482	0.0244	0.0013	5.33	6.06	4.61	4.61
	$\lambda = 0.25$; $L = 2.998$	0.0142	0.0377	0.0244	0.0013	2.99	3.40	2.58	2.58
	$\lambda = 0.20$; $L = 2.962$	0.0166	0.0346	0.0244	0.0013	2.30	2.61	1.99	1.99
	$\lambda = 0.10$; $L = 2.814$	0.0209	0.0290	0.0244	0.0013	1.03	1.17	0.89	0.89
	$\lambda = 0.05$; $L = 2.615$	0.0230	0.0267	0.0246	0.0014	0.45	0.52	0.39	0.39
Notch	$\lambda = 0.40$; $L = 3.054$	0.0004	0.0238	0.0053	0.0006	6.19	9.80	2.57	2.57
	$\lambda = 0.25$; $L = 2.998$	0.0016	0.0164	0.0058	0.0007	3.54	5.09	2.00	2.00
	$\lambda = 0.20$; $L = 2.962$	0.0026	0.0140	0.0059	0.0007	2.68	3.83	1.54	1.54
	$\lambda = 0.10$; $L = 2.814$	0.0051	0.0107	0.0068	0.0009	1.04	1.44	0.64	0.64
	$\lambda = 0.05$; $L = 2.615$	0.0058	0.0082	0.0065	0.0009	0.43	0.61	0.26	0.26
Slit	$\lambda = 0.40$; $L = 3.054$	0.0000	0.0208	0.0042	0.0030	1.16	1.85	0.47	0.47
	$\lambda = 0.25$; $L = 2.998$	-	-	-	-	-	-	-	-
	$\lambda = 0.20$; $L = 2.962$	-	-	-	-	-	-	-	-
	$\lambda = 0.10$; $L = 2.814$	-	-	-	-	-	-	-	-
	$\lambda = 0.05$; $L = 2.615$	-	-	-	-	-	-	-	-

Table 2 shows that the lower parameter value λ was given, the value of C_p and C_{pk} also getting lower. This means that with the lower C_p, the capability process is low, and the low value of C_p indicates the process is producing a nonconforming product to the specification.

When the C_{pk} value is negative, it shows that the mean process is beyond the specification limit, while $C_{pk} = 1.0$ means that one variation of the process is out of specification, $C_{pk} < 1.0$ means that the process will produce a nonconforming to the specification product, and $C_{pk} = 0$ shows the mean and the value of C_{pk} is equal to specification.[4]

Table 2 shows that the value of C_{pk} is lower as the value of λ decreased, it means that the process will produce a nonconforming to the specification product.

The optimum value of λ as shown in Table 2 is $\lambda = 0.20$ and $L = 2.962$.

For defect type slit, the value of C_p and C_{pk} was very close to 1.0 for Shewhart p Control Chart and the value of C_p and C_{pk} not available for ISRT p EWMA Control Chart because there was a special cause condition so that the process has to be stopped to conducting a full inspection on machine setup and machine configuration.

Comparing the value of C_p and C_{pk} of Shewhart p Control Chart and the ISRT p EWMA Control Chart shows that the ISRT p EWMA Control Chart can detect a small shift at the parameter of $\lambda = 0.20$ and $L = 2.962$.

4. Conclusion

Based on the calculation, the ISRT p EWMA Control Chart can detect a small shift at the parameter of $\lambda = 0.20$ and $L = 2.962$.

The ISRT p EWMA Control Chart is suitable for whether np or p_i is greater or equal to 5. The calculation showed that the chips defect, dirty defect, notch defect, the ISRT p EWMA Control Chart could detect a small shift, while for slit defect, the ISRT p EWMA Control Chart was failed to detect a small shift.

The lowest λ value on the ISRT p EWMA Control Chart is $\lambda = 0.20$ and $L = 2.962$, to find the value of capability process larger than 1.0.

5. References

[1] Montgomery, D. C., 2009. *Introduction to Statistical Quality Control 6th Edition*. New York: Wiley

[2] Sukparungsee, S., 2014, An EWMA p Chart Based On Improved Square Root Transformation, *World Academy of Science, Engineering and Technology International Journal of Physical and Mathematical Sciences*, Vol 8 No 7, pp. 1045 – 1047

[3] Tsai, T-R., Lin, C. C., Wu, S-J, 2006, Alternative attribute control chart based on improved square root transformation, *Tamsui Oxj. J. Math. Sci.*, Vol 22 no 1, pp 61-72.

[4] Arumsari, J N Rifqi, 2020, Performance Evaluation of an EWMA p Chart Based on Improved Square Root Transformation to detect Small Shift Process Variation, *IOP Conf. Ser.: Mater. Sci. Eng.*, 847 (2020) 012032.

[5] Tsai, Chen-Fang, Shin-Li Lu, Chi-Jui Huang, 2015, Design of An Extended Nonparametric EWMA Sign Chart, *International Journal of Industrial Engineering: Theory, Applications and Practice*, Vol 22, No 6, pp 705-716.

[6] Sukparungsee, S., Gabriele Mititelu, 2016, A Modified Poisson Exponentially Weighted Moving Average Chart Based on Improved Square Root Transformation, *Thailand Statistician*, Vol 14 No 2, pp. 197-202

Capability process on Shewhart p control chart and ISRT p EWMA control chart on shift drum production

ORIGINALITY REPORT

18%	9%	15%	5%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Arumsari, J N Rifqi. "Performance Evaluation of an EWMA p Chart Based on Improved Square Root Transformation to detect Small Shift Process Variation", IOP Conference Series: Materials Science and Engineering, 2020 Publication	4%
2	Shey-Huei Sheu, Tse-Chieh Lin. "The Generally Weighted Moving Average Control Chart for Detecting Small Shifts in the Process Mean", Quality Engineering, 2003 Publication	2%
3	moam.info Internet Source	2%
4	Muhammad Aslam, Aamir Saghir, Liaquat Ahmad. "Introduction to Statistical Process Control", Wiley, 2020 Publication	1%
5	Submitted to Yasar University Student Paper	1%

6	dl4a.org Internet Source	1 %
7	Submitted to Cankaya University Student Paper	1 %
8	Wahyukaton, Siti Qodriyah. "Determining a combination of factors on rubber end manufacturing using taguchi method at PT. Agronesia Bandung", IOP Conference Series: Materials Science and Engineering, 2017 Publication	1 %
9	www.tci-thaijo.org Internet Source	1 %
10	Submitted to Higher Education Commission Pakistan Student Paper	1 %
11	Submitted to Kingston University Student Paper	1 %
12	id.scribd.com Internet Source	1 %
13	Submitted to University of Teesside Student Paper	<1 %
14	International Journal of Quality & Reliability Management, Volume 28, Issue 8 (2011-09-13) Publication	<1 %
	karyailmiah.unisba.ac.id	

15 Internet Source <1%

16 Hao Wu, Yang Dai, Chi Wang, Xiao-wen Xu, Xiao-min Jiang. "Identification and forewarning of GNSS deformation information based on a modified EWMA control chart", Measurement, 2020 <1%
Publication

17 Ong Hong Choon, Poh-Ying Lim. "Effects of Heavy Tailed Distribution on Statistical and Neural Network Based Control Charts", 2009 International Conference on Computer Technology and Development, 2009 <1%
Publication

18 Shuchuan Lo. "Web service quality control based on text mining using support vector machine", Expert Systems with Applications, 2008 <1%
Publication

19 Buser, Joel T., and Wolfgang Staud. "", 23rd Annual BACUS Symposium on Photomask Technology, 2003. <1%
Publication

20 Claude R. Superville, Benjamin M Adams. "An evaluation of forecast-based quality control schemes", Communications in Statistics - Simulation and Computation, 1994 <1%

Publication

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	Off		