THE POSSIBILITY OF USING CONTROL CHARTS IN QUALITY CONTROL OF THE PRODUCTION PROCESS

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Abstract: The article we will present on the use of control diagrams (charts) of the production process, specifically to assurance the quality on milling machine. The use and effectiveness in the application in the production process will be evaluated by comparing the waveforms in the diagrams. Various types of diagrams, which operate on different statistical characteristics, were selected as a statistical tool for regulating the detection and assessment of stability of the manufacturing process.

1 Introduction

The production process should be continually monitored and controlled. It is therefore necessary to know and use methods, tools and techniques of statistical process control to improve and maintain the quality of products and processes that allow us to monitor and report on the process of quantification of image. Introduction of Statistical Process Control – SPC, using control charts and associated with the detection capability of the manufacturing process is carried out in retaliation, which are characterized by high accuracy. In general, control charts used to improve the quality parameters of production and in the prevention of errors in the output, in the production process. Help prevent unnecessary changeovers production lines, which could create downtime and will increase the cost of the production process.

Control chart indicates the possibility of the presence of discrete causes in the process when the point outside the regulatory borders. It should also follow some typical cluster points, none of which does not lie outside these limits, but which may also indicate the presence of a discrete causes [1], [2].

The measured values of X (product parameter) are characterized by their mean value and variability. Wednesday to regulate the distribution of measured values is used $\overline{X}$ *-chart* (control means selection means) or *Mediagram* (regulation through the selection of the median). For controlling the variability in the distribution of measured values is used *R-chart* (control by tendering variation margin) or *s-chart* (control via sample standard deviation). In general, the chart contains a center line that represents the mean value for the in-control process [3], [4]. Two other horizontal lines, called the upper control limit (UCL) and the lower control limit (LCL), are also shown on the chart. These control limits are chosen so that almost all of the data points will fall within these limits as long as the process remains in-control. If the monitored process operates only accidental causes, then all polygon points in a control chart are between LCL and UCL, UCL and LCL lines define the scope permissible variation value, approximately 99.7% (6б) values will lie within this zone. Then the process of statistically controlled state, that is the statistical right. USL (Upper Specification Limit) is the upper tolerance limit and LSL (Lower Specification Limit) is lower tolerance limits. Control charts work with the Type I error 0.0027.

Control charts for measurable quality characteristics required for the right application to verify four assumptions: normality of data, constant mean value, standard deviation and constant data independence. For the analysis of variable and attributive characters they have been developed various types of control charts. It is advisable to construct a pair of control charts, one for monitoring the variability of the character and quality second to monitor the centring of the character quality [5], [6], [7], [8]. Into classification of control charts is engaged STN ISO 8258:1995 generally there are two types of control charts:

- measurement control charts - data on measurable variable obtained by measuring and recording the character numerical values for each of the items in the subgroup,
- comparison of control charts - data obtained in recording the presence or absence of a specific character for each of the items in the subgroup.

For regulating measurement pairs are used:

- charts for the average $\overline{X}$ and standard deviation s
- chart for average $\overline{X}$ and range R,
- chart for the median Me and range R.

Control charts for data obtained by comparing (qualitative and measurable quality characteristics) (Control Charts for Attributes) are:

- chart for the number of nonconformities, defects,
- chart for number of nonconformities per unit,

- chart for the share of nonconforming units.

For each of control charts, there are two different situations:

- core values are fixed (very unlikely in practice),
- core values are not established,
- core values are fixed (very unlikely in practice).

In this paper are used only control charts for measuring.

Process capability reflects the ability of the manufacturing process or equipment to achieve the prescribed quality requirements. To improve the process of stabilization is required, the stable process if it does not change the average or standard deviation. Statistically controlled process means that the process is operating only the effects of random and systematic causes of instability are eliminated. To evaluate the process are used different capability index which compare a prescribed allowable variability in a given tolerance limits to the actual variability observed character achieved a statistically controlled processs. For monitoring process capability indices are used C_p, C_{pk} and C_{pm} who is allowed to count only upon proof that the process is in statistical mastery of state.

Capability index C_p is a measure of the potential ability of the process to ensure that the monitored quality feature lay within the tolerance limits. This work describes the process variability. Its disadvantage is that it does not consider the middle of the distribution of the measured values with respect to a desired target value, and to require the two tolerance limits. Take values from 0 to 2, and of the numerical value to determine the process capability. While the index C_p is an indicator of potential process capability, that is how the process could be, so the index C_{pk} is an indicator of the current process capability. Capability index C_{pk} takes into account not only the variability, but the location of the reference values of tolerance mark of quality in the field. Thus characterizes the true process capability to comply with the prescribed tolerance limits. The disadvantage of this index is that if the mean value μ moving away from the target value, and does not change its deviation б, deteriorating. The index C_{pk} can take values from $(-\infty,\infty)$. Capability index C_{pm} called Taguchi capability index, removes some of the shortcomings and indexes C_p and C_{pk}. This index compares the maximum permissible variation observed quality characteristic determined width of the tolerance band of the real variability around the target value. The value of this index will be calculated from the interval $(0,\infty)$.

2 Process measurement evaluation

For monitoring capabilities metalworking lathe (milling machine) comply with setting and maintaining the quality control charts were selected. Measured object was sprocket with an internal diameter of $28 \pm 0.05\ mm$. The measurements were performed on a digital caliper MITUTOYO.

According to the standards of construction Shewhart control charts it is recommended to measure the products of approximately equal intervals and in groups, which consist of the same product to the same measurable units and the same number of values in each subgroup (STN ISO 8258:1995).

There have been five measurements every hour and included a total of 25 selections, ie the number of subgroups is k = 25 and range of subgroups n = fifth The prescribed limits are 27.95 mm and 28.05 mm. Based on the measured values, the averages are evaluated. The measured values were tested for nomality, from Figure 1 it is clear that they have a normal Gaussian distribution. Data normality was confirmed by the Shapiro-Wilco test, p-value is 0,1513 it is probably null-hypothesis is *accepted* at the significance level, p>0.05, the population is normally distributed.

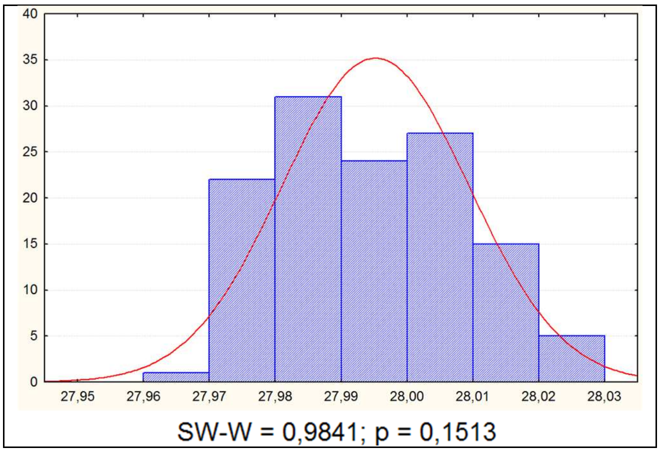

Figure1 Verify data normality

In Table 1 are calculated in the final group of central tendency and variability needed to construct control charts.

Table 1 Values for constructing control charts

Group	Average [mm]	Range [mm]	Standard deviation	Median [mm]
1	27,9854	0,0340	0,0148	27,9770
2	27,9968	0,0250	0,0114	27,9910
3	27,9978	0,0280	0,0107	27,9950
4	27,9944	0,0190	0,0081	27,9900
5	27,9892	0,0320	0,0145	27,9800
6	28,0022	0,0290	0,0120	28,0050
7	27,9846	0,0170	0,0069	27,9820

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8	27,9906	0,0350	0,0132	27,9880
9	27,9828	0,0280	0,0117	27,9770
10	28,0040	0,0390	0,0149	28,0010
11	27,9996	0,0410	0,0151	28,0030
12	28,0084	0,0270	0,0106	28,0050
13	27,9992	0,0590	0,0267	27,9980
14	27,9910	0,0280	0,0125	27,9940
15	28,0032	0,0200	0,0076	28,0010
16	27,9964	0,0260	0,0109	27,9910
17	27,9904	0,0310	0,0122	27,9920
18	27,9896	0,0540	0,0204	27,9900
19	27,9974	0,0370	0,0158	27,9900
20	27,9994	0,0210	0,0079	28,0010
21	27,9988	0,0290	0,0144	27,9900
22	27,9892	0,0420	0,0169	27,9830
23	27,9968	0,0270	0,0120	27,9950
24	27,9968	0,0340	0,0127	27,9930
25	27,9958	0,0520	0,0216	28,0010
Average	**27,9952**	**0,0326**	**0,0134**	**27,9925**

Before determining the central lines and control lines, it is necessary to calculate the central tendency and variability - each choice means $\bar{x}$, range R, standard deviation and median. Consequently, for these values, it calculates the average sample mean, the average variance, the average standard deviation and the average median (1) as:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i\,,\quad R = x_{\max} - x_{\min}\,,\quad s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i-\bar{x})_2}\,,$$

$$Me = x_{\left(\frac{n+1}{2}\right)} \quad \text{or} \quad Me = \frac{1}{2}\left(x_{\left(\frac{n}{2}\right)} + x_{\left(\frac{n+2}{2}\right)}\right),$$

$$\bar{\bar{x}} = \frac{\sum \bar{x}}{k}\,,\quad \bar{R} = \frac{\sum R}{k}\,,\quad \bar{s} = \frac{\sum s}{k}\,,\quad \bar{M}_e = \frac{\sum Me}{k} \qquad (1)$$

a) Control charts for average and range ($\bar{X}$, R)

- Central line: $CL_x = \bar{\bar{x}}$ a $CL_R = \bar{R}$.
- Control limits:

$UCL_x = \bar{\bar{x}} + A_2.\bar{R} \quad LCL_x = \bar{\bar{x}} - A_2.\bar{R}$

$UCL_R = D_4.\bar{R} \quad LCL_R = D_3.\bar{R}$.

b) Control charts for average and standard deviation ($\bar{X}$,s)

- Central line: $CL_x = \bar{\bar{x}}$ a $CL_s = \bar{s}$.
- Control limits:

$UCL_x = \bar{\bar{x}} + A_3.\bar{s} \quad LCL_x = \bar{\bar{x}} - A_3.\bar{s}$

$UCL_s = B_4.\bar{s} \quad LCL_s = B_3.\bar{s}$.

c) Control charts for median and range (Me, R)

- Central line: $CL_{Me} = \overline{Me}$ a $CL_R = \bar{R}$.
- Control limits:

$UCL_{Me} = \overline{Me} + A_4.\bar{R} \quad LCL_{Me} = \overline{Me} - A_4.\bar{R}$

$UCL_R = D_4.\bar{R} \quad LCL_R = D_3.\bar{R}$.

Coefficients A_2, A_3, A_4, B_3, B_4, D_3, D_4, d_2, C_4 are depended on the sample size and the tax table, for n=5 it isTable 2.

Table 2 Coefficients for calculating regulatory limits for the scope of subgroup n = 5

A_2	A_3	A_4	B_3	B_4	D_3	D_4	d_2	C_4
0,577	1,427	0,690	0,000	2,089	0,000	2,114	2,326	0,940

Statistical stability, we research it by control chart, the control chart, we find signs of instability: points beyond regulatory limits, 7 consecutive points above the center line, 7 consecutive points below the central line, 7 consecutive points in a rising line, 7 consecutive points in descending row.

Table 3 The regulatory limits and central lines for ($\bar{X}$, R)

Control chart for average [mm]		Control chart for range [mm]	
CL	*27.9952*	**CL**	*0,0326*
LCL	*27.9764*	**LCL**	*0*
UCL	*28.0140*	**UCL**	*0,0688*

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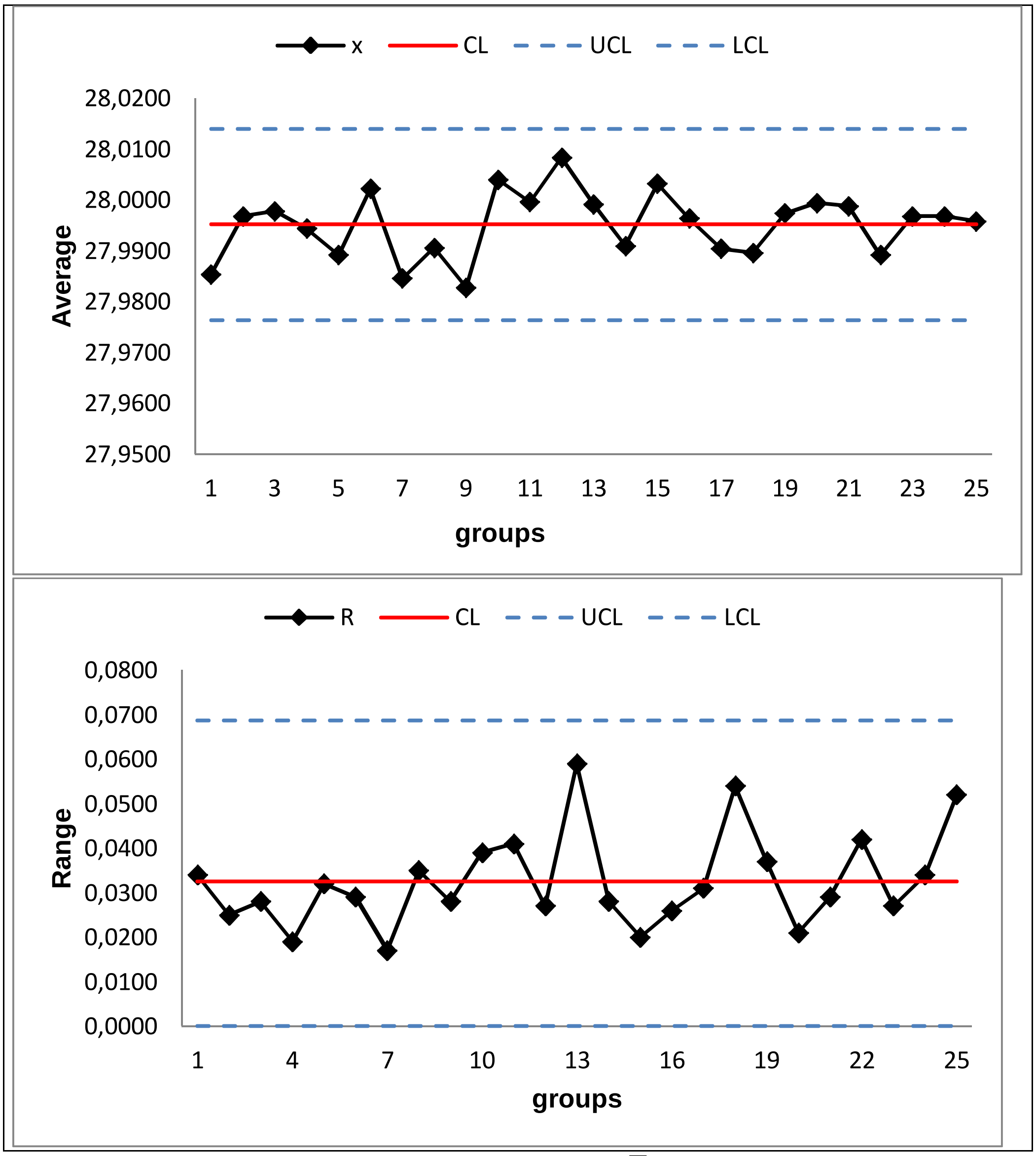

Figure 2 Control charts ($\overline{X}$, R)

In Figure 2 are displayed one below the other control charts, and the range of diameters, and how is the range of diameters diagrams seen that the process is stable, since all points are between the upper and lower boundaries of regulatory.

Table 4 The regulatory limits and central lines for ($\overline{X}$,s)

Control chart for average [mm]		Control chart for standard deviation [mm]	
CL	*27.9952*	**CL**	*0,0134*
LCL	*27.9760*	**LCL**	*0*
UCL	*28,0143*	**UCL**	*0,0280*

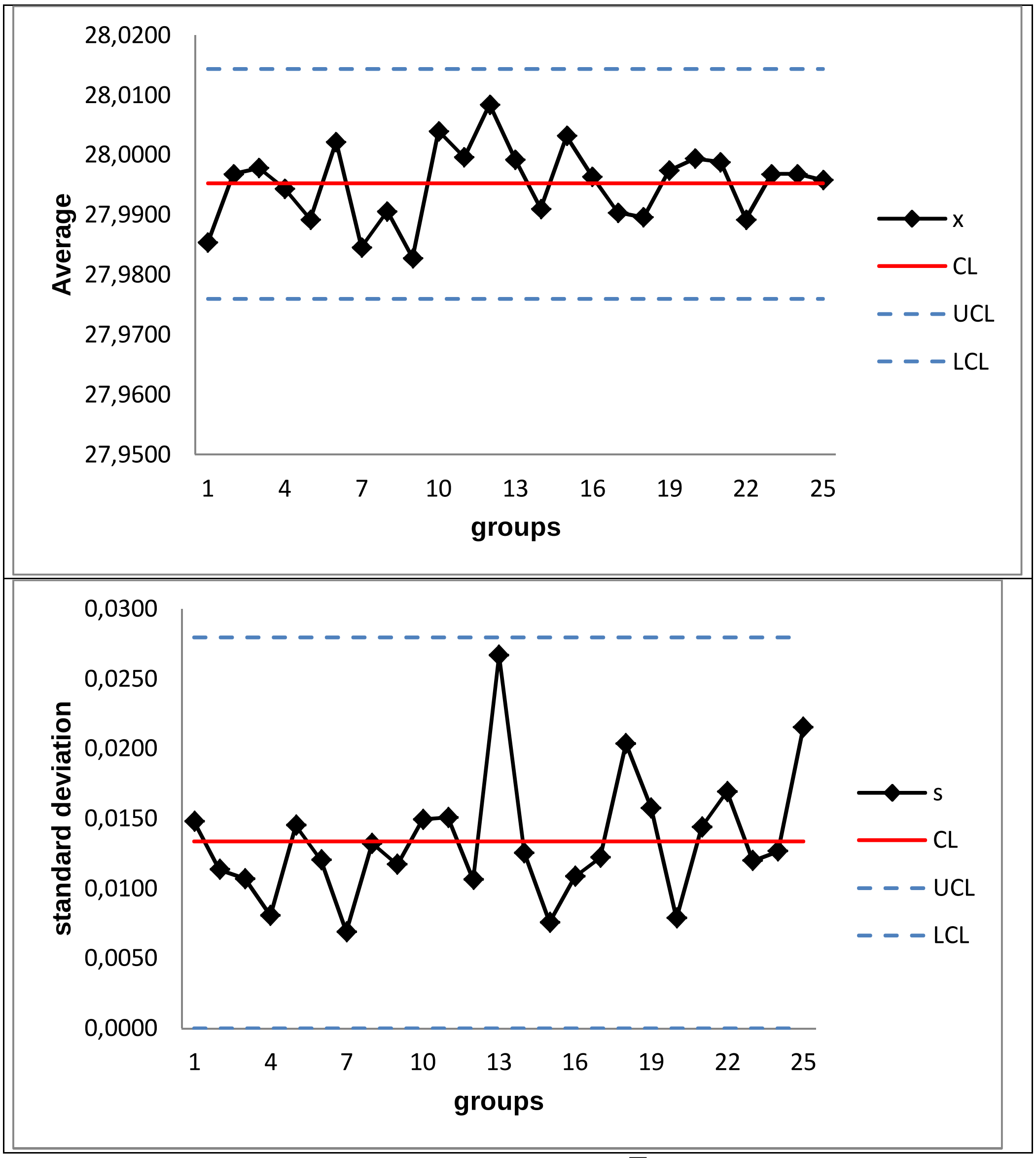

Figure 3 Control charts ($\overline{X}$, s)

In Figure 3 are shown below each other control charts means and sample standard deviations. Neither point calculated exceeded regulatory limits, so the process is stable. When analyzing control charts for the variability of the manufacturing process using statistical characteristics of the *R* and *s* can state a similar pattern of these curves.

Table 5 The regulatory limits and central lines for (Me, R)

Control chart for median [mm]		Control chart for range [mm]	
CL	27.9925	CL	0,0326
LCL	27.9701	LCL	0
UCL	28.0150	UCL	0,0688

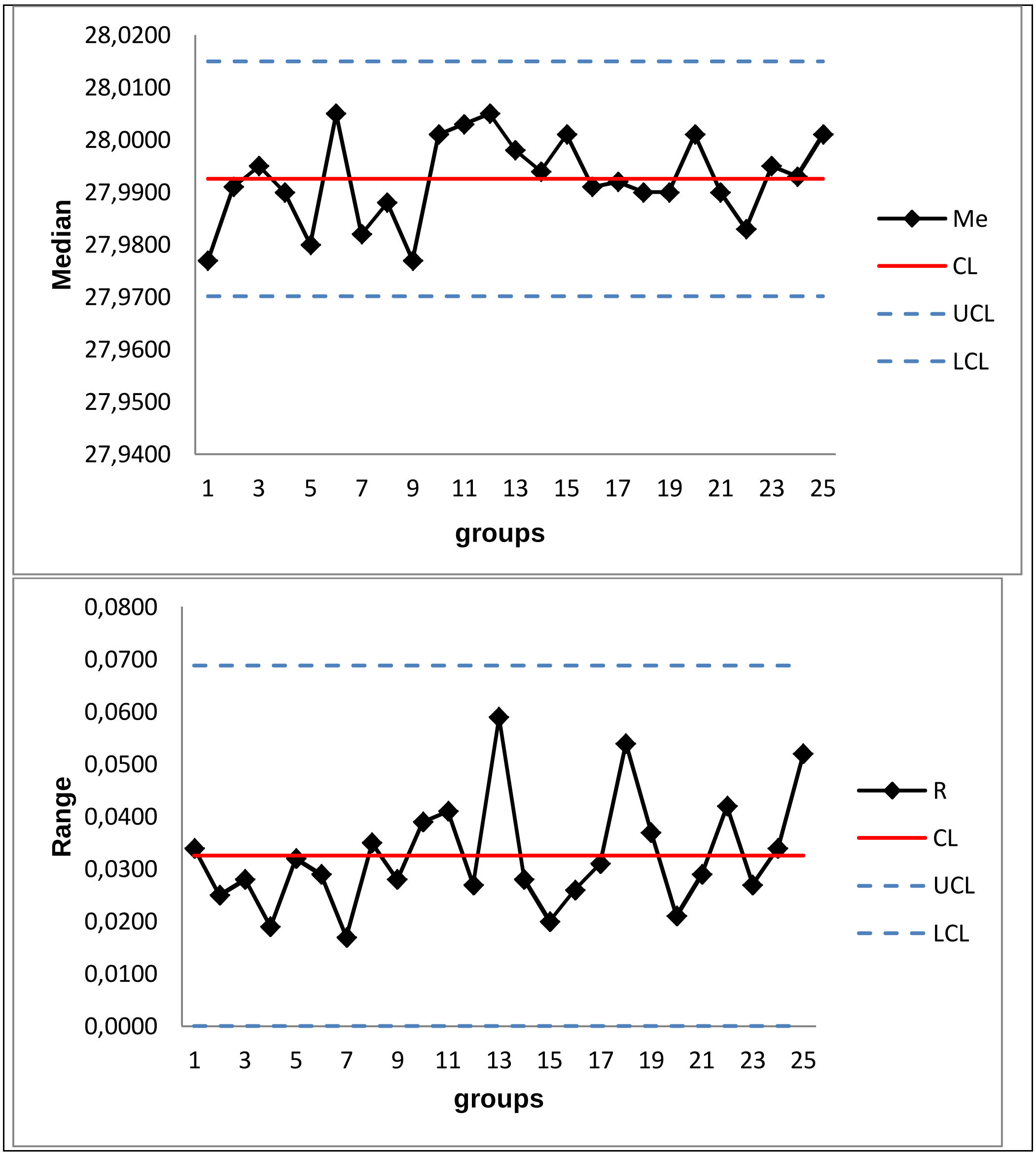

Figure 4 Control charts (Me, R)

In Figure 4 are shown below each other control charts for median and range. As shown in the figure there are not visible from a trend or a group of points that would signal the presence of a discrete causes of variation. The process is stable.

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Indicators for capacity control charts ($\overline{X}$, R) (2) are:

$$C_p = \frac{d_2(USL - LSL)}{6\overline{R}} = 1{,}1906$$

$$C_{pk} = \min\left\{\frac{d_2(USL - \overline{\overline{x}})}{3\overline{R}}, \frac{d_2(\overline{\overline{x}} - LSL)}{3\overline{R}}\right\} \qquad (2)$$

$C_{pk} = \min\{1.3051, 1.0761\} = 1{,}0761$.

The index value $C_p > 1$, $C_{pk} > 1$ say that it is the compliance of the production process. Valid $C_{pk} < 1{,}25$ account of the process is a good fit for standard products.

Conclusion

Identification of the problems associated with poor quality products, identifying the causes of and continuous improvement is key to maintaining and improving the quality of processes and products are essential.The article is an example of using control charts for monitoring capabilities milling machine comply with setting. Control charts are used to routinely monitor quality. A control chart represents a picture of a process over time. A control chart tells you if your process are in statistical control. The ideas above apply to more than just manufacturing processes. We can use run charts and control charts to monitor waiting times for bank customers, numbers of complaints, customer satisfaction ratings, delivery times, and so on.

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