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THE PROCESS CAPABILITY STUDY BY THE FLANGE SHAFT PRODUCTION

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Katarína Lestyánszka Škůrková[1] – *orcid ID: 0000-0003-0088-5454*
Alena Pauliková[1] – *orcid ID: 0000-0002-2959-5656*
[1]Slovak University of Technology in Bratislava, **Slovakia**

Abstract: Ensuring the process0capability currently means the warranty, that produced products will be0in accordance with requirements - from company´s side or from customer´s side. This study focuses on the statistical control of flange shaft process capability by serial production0in company focused on products for automotive. The flange shaft process is evaluated by control charts,0specifically by control chart for average and range ($\overline{x}$, R). As the results showed, based on diagram for average and range we are able0to say that the turning process is under the statistical control. Also, we had finished the0reguest for capability of process, where0the indexes of capability process C_{pk1} and C_{pk2} are higher than the determined value on 1.33 point. The normality of the measured values was verified by histogram. Obtained values are: C_{pk1} = 1.645 a C_{pk} = 1.52. Therefore, we can consider the process as capable.

Key words: process, flange shaft, normality, stability, capability

1. INTRODUCTION

Effective quality management of manufactured products is a factior determining the development of manufacturing companies (Pacana, A. 2020). Manufacturing processes of technically complex products require highly standardised methods to fulfil technical and customer specifications. To accomplish the demanded specifications, various methods, which can be applied at different phases of the product life cycle, have been developed. One of these methods, within the manufacturing phase, is the process capability index (PCI) (Bracke, S. 2018). Currently, each manufacturing organization resists constraints and threats within its competitors (Jankajová, Kotus 2015). The process capability means the process ability to permanently achieve defined quality criterions and also the ability to work with some accuracy (Lestyánszka, 2015). The process capability evaluation is today often required by customer, because it is an evidence for him, that the product was made in stable production conditions where the required quality criterions were regularly ensured. This is also an information about the fact what accuracy can he count in the future with. For the producer is it very important information, which enables for him the choice for suitable machine for producing of

some products, estimate the risks of non – conforming products creation and to plant the preventive and corrective actions for improvement. (Kučerová, 2011)
The purpose of the statistical process control is to find, if all significant causes of process instability were removed. 0here is required that the mean value of the monitored quality character and its variability are constant in time. The best way to find this information is by using the Shewhart control charts and represents the preparatory stage of statistical regulation. (Hrubec, 2001)
The starting point for statistical regulation is to well manage the production processes (Lestyánszka, 2013). The production0process is considered as well managed, if it is affected by random causes only. If there is a large number of random causes in a process, the resulting distribution we can characterize as normal. This method is mainly established for normal distributed processes (Kotz, S. 2005).0Currently we evaluate the process capability by process capability indexes C_p (characterize the process dispersion) and C_{pk} (characterize the process location in0tolerance area). We can consider the process as capable if the indexes values C_p and C_{pk} are higher than 1.33 point. (Hrubec, 2009)
Between input data belong:

- capable measuring equipment,
- production conditions of serial production,
- capable production equipment,
- process is statistically controlled (stable),
- technical and other specifications are defined by customer requirements,
- nominal value is located in the centre of tolerance range.
- measured values from the process are characterised by normal distribution,

Using this method, it is necessary to consider and to apply these information and findings from previous process observation. (Hrubec, 2001)

2. METHODOLOGY OF RESEARCH:

Process description:
Preliminary process capability
Working operation: *turning*
Character: *average*
Nominal value: *100.005 mm (can be obtained after the last machining operations)*
Lower tolerance limit (LSL): *100.005 mm*
Upper tolerance limit (USL): *100.025 mm*
Measuring equipment: *average measurement*
Number of measurements: *N = 100 (for preliminary process capability)*
N = 125 (for long term process capability)
Sampling interval: *one working shift*

The observed organisation is situated in Western Slovakia and deals with the manufacturing of products for automotive. This article is focused on statistical evaluation of the process by production of flange shaft production in connection with statistical regulation of the process. The criterions for capability evaluation are indexes P_p and P_{pk} (preliminary process capability) and C_p a C_{pk} (long term process capability). Cp represents the ratio between the process scattering and the given tolerance area. Regarding the manufacturing deviations the position of the manufacturing´s arithmetic mean inside the ratio considers C_{pk} (Härdle, W. 2015). In terms of product specification is as the critical sign considered the average of flange shaf 100.005 mm. Therefore, in the turning process the monitored sign´s size is technologically prescribed average ø100,005 ÷ 100,025 mm. This quality sign is very important for the customer and the customer requires to fulfil given tolerance band up to 100%. This process is in the observed organisation evaluated only by the preliminary process capability – P_p and P_{pk} indicators. Process capability is divided into two perspectives: process capability C_p and critical process capability C_{pk} (Dietrich, E. 2010). The customers also requires to provide the long term process capability by C_p and C_{pk} indicatiors. The flange shaft average was measured by average measurement, where the average measurement capability was verified, and the average measurement was considered as capable. The normal distribution of measured values will be controlled by histogram. By statistical regulation of turning process will be used the Shewhart control chart for average and range ($\overline{X}$,*R*).

The measured values are used for the calculation of: (Škůrková, K.L. 2015)

Average value of attribute in subgroup:

$$\overline{X_i} = \frac{1}{n}\sum_{j=1}^{n} X_{ij} \qquad (1)$$

for $i = 1, 2 .... k$ and for $j = 1, 2 ...n$,

where: *i* – sequential number of subgroups,

j – sequential number of measured value in subgroup,

k – number of subgroups,

n – subgroup size,

X_{ij}– measured value in *i*-th subgroup

Range in subgroup:

$$R_i = MAX(X_{ij}) - MIN(X_{ij}) \qquad (2)$$

for $i = 1, 2 ... k$ and for $j = 1, 2 ...n$

where $MAX(X_{ij})$ and $MIN(X_{ij})$ are maximum and minimum value measured in the *i*-th subgroup.

Average of process:

$$\overline{\overline{X}} = \frac{1}{k}\sum_{i=1}^{k} \overline{X_i} \qquad (3)$$

Average range:

$$\overline{R} = \frac{1}{k}\sum_{i=1}^{k} R_i \qquad (4)$$

where: R_iX_i - ranges and averages in the *i*-th subgroups (*i*=1, 2, ...*k*).

Calculation of control limits:

Upper and lower control limits for range and average:

$$UCL_R = D_4 . \overline{R} \quad (5)$$

$$LCL_R = D_3 . \overline{R} \quad (6)$$

$$UCL_{\overline{X}} = \overline{\overline{X}} + A_2 . \overline{R} \quad (7)$$

$$LCL_{\overline{X}} = \overline{\overline{X}} - A_2 . \overline{R} \quad (8)$$

where D_4, D_3 and A_2 are constants of control limits; they are changing depending on subgroup size n (in our case n = 5) the values: $D_3 = 0.000$, $D_4 = 2.114$, $A_2 = 0.577$.

The preliminary process capability indexes

$$\hat{\sigma}_{TOT} = \left(\frac{1}{N-1} \sum_{i=1}^{k} \sum_{j=1}^{n_i} (x_{ij} - \bar{\bar{x}})^2 \right)^{\frac{1}{2}} \quad (9)$$

$$\sum_{i=1}^{k} n_i = N \quad (10)$$

$$P_p = \frac{USL-LSL}{6\sigma_{tot}} \quad (11)$$

$$P_{pk} = \min \left\{ \frac{USL-\mu}{3\sigma_{TOT}} \middle| \frac{\mu-LSL}{3\sigma_{TOT}} \right\} \quad (12)$$

The long-term process capability indexes

Process capability index C_p

$$C_p = \frac{USL - LSL}{6.\hat{\sigma}} = \frac{T}{6.\hat{\sigma}} \quad \text{(DIN ISO 3534-2:2013-12)} \quad (13)$$

Corrected process capability index C_{pk}

$$C_{PK} = \frac{USL - \overline{\overline{X}}}{3.\hat{\sigma}} \quad (14) \qquad C_{PK} = \frac{\overline{\overline{X}} - LSL}{3.\hat{\sigma}} \quad (15)$$

Where: USL, LSL - upper and lower specification limits

T - tolerance of attribute

$\hat{\sigma}$ - estimation of process standard deviation

There is a condition: $C_p \geq 1.33$ and $C_{pk} \geq 1.33$ (where is accepted the lower of C_{pk} value). (Hrubec, 2014)

3. RESULTS AND DISCUSSION

The preliminary process capability

In the turning process by production of flange shaft were measured values for 100 values to provide the preliminary process capability. Figure 1 represents all measured values. As can be seen, all measured values are inside the tolerance field.

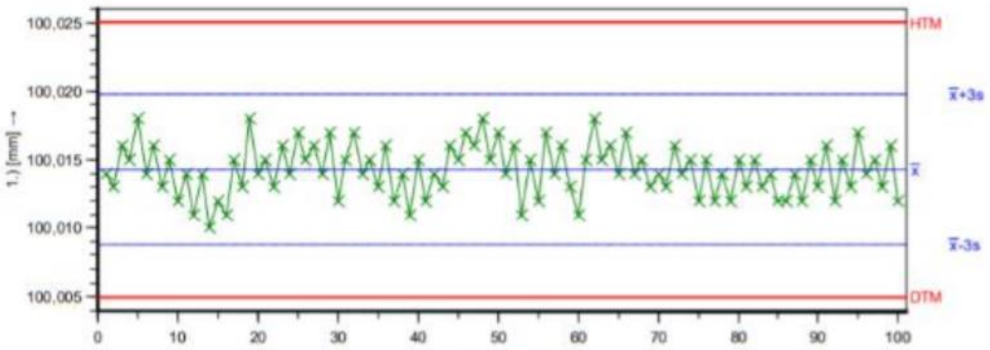

Fig. 1 Measured values (Gálisová, 2020)

As the next step, we check up the normality of the process. As a confirmation of the normal distribution, histogram and likelihood network has been constructed, as can be seen in Figure 2.

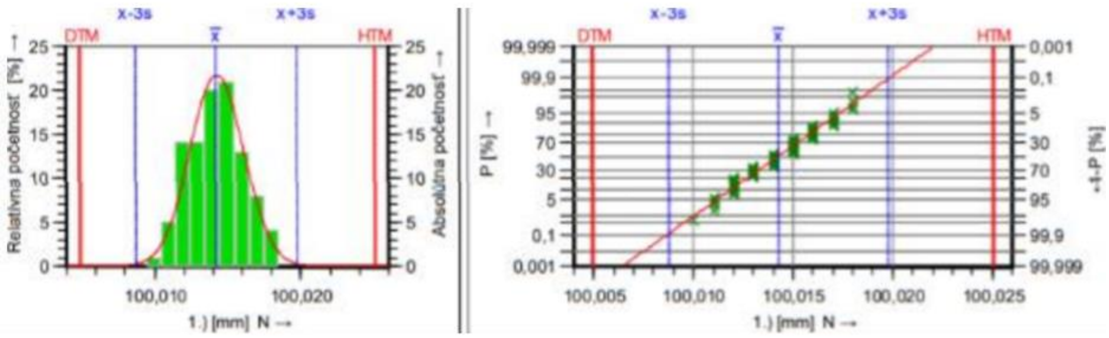

Fig. 2 Histogram and likelihood network (Gálisová, 2020)

As can be seen in Figure 2, this process has the normal contribution, so normality was confirmed.

As the last step, there were capability indexes calculated.

Obtained values:

$P_p = 1.82$

$P_{pk} = 1.68$

So, after preliminary process capability confirmation we can start with the long-term process capability.

The long term process capability

In the turning process by production of flange shaft were measured values for 25 subgroups. Measured values of 125 flange shaft can be seen in Table 1.

Table 1
Measured values of the flange shaft (Gálisová, 2020)

k	X1	X2	X3	X4	X5	Average	Range
1	100.018	100.016	100.016	100.012	100.013	100.015	0.006
2	100.015	100.014	100.011	100.014	100.016	100.014	0.005
3	100.017	100.017	100.015	100.012	100.010	100.0142	0.007
4	100.013	100.012	100.012	100.015	100.014	100.0132	0.003
5	100.016	100.015	100.017	100.013	100.011	100.0144	0.006
6	100.012	100.017	100.014	100.015	100.017	100.015	0.005
7	100.015	100.014	100.016	100.013	100.012	100.014	0.004
8	100.013	100.015	100.013	100.014	100.016	100.0142	0.003
9	100.016	100.013	100.011	100.012	100.014	100.0132	0.005
10	100.011	100.016	100.015	100.012	100.018	100.0144	0.007
11	100.014	100.012	100.018	100.014	100.014	100.0144	0.006
12	100.012	100.014	100.015	100.012	100.016	100.0138	0.004
13	100.015	100.011	100.016	100.015	100.018	100.015	0.007
14	100.014	100.015	100.014	100.013	100.013	100.0138	0.002
15	100.012	100.012	100.017	100.016	100.017	100.0148	0.005
16	100.016	100.014	100.014	100.012	100.013	100.0138	0.004
17	100.013	100.013	100.015	100.015	100.015	100.0142	0.002
18	100.018	100.016	100.013	100.013	100.011	100.0142	0.007
19	100.014	100.015	100.014	100.017	100.014	100.0148	0.003
20	100.015	100.017	100.013	100.014	100.012	100.0142	0.005
21	100.016	100.016	100.016	100.015	100.015	100.015	0.003
22	100.016	100.018	100.014	100.013	100.011	100.0144	0.007
23	100.014	100.015	100.015	100.016	100.013	100.0146	0.003
24	100.017	100.017	100.012	100.012	100.011	100.0138	0.006
25	100.015	100.014	100.015	100.017	100.015	100.0152	0.003

Calculated characteristics for average $\overline{X}$ and range *R* are used for plotting the control charts.

For ($\overline{X}$,R) control charts are valid these control limits:

UCL_X = 100.0170
LCL_X = 100.0115
CL_X = 100.0143

UCL_R = 0.0099
LCL_R = 0
CL_R = 0.00472

Control chart for range

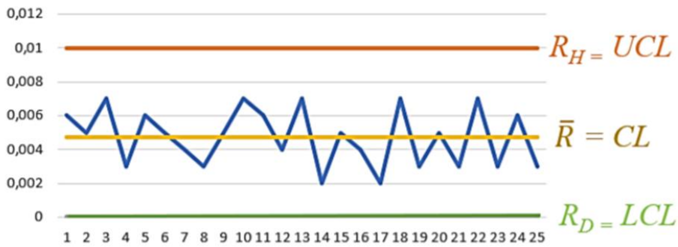

Fig. 3 Control chart for range (Gálisová, 2020)

Control chart for average (Gálisová, 2020)

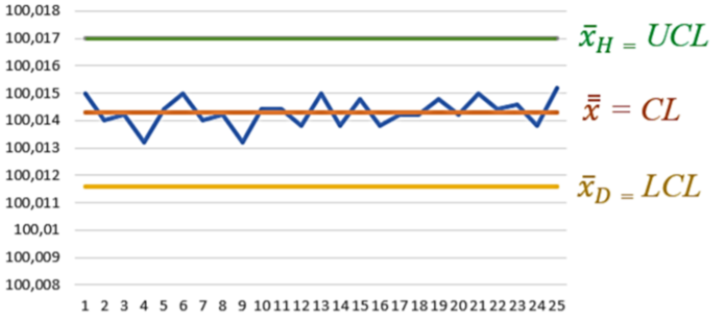

Fig. 4 Control chart for average (Gálisová, 2020)

The final measurement average, i.e., the process ability to hold the target value is well above the required limit. The central limits have not been exceeded. On the basis of this results, as can be seen in Figure 3 - Control chart for range *R* and in Figure 4 - Control chart for average $\overline{X}$, we can consider the process as stable.

The normal distribution was confirmed by histogram, as can be seen in Figure 5.

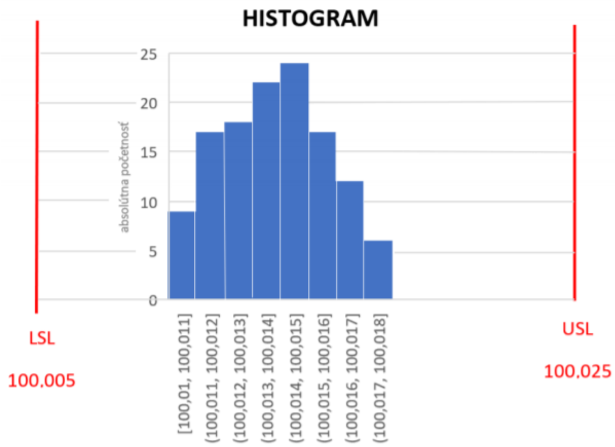

Fig. 5 Histogram (Gálisová, 2020)

Subsequently we approach to process capability indexes C_p a C_{pk} calculation.

Obtained values: **C_p = 1.64 C_{pk} = 1.52**
Based on the process capability evaluation we can consider as follows: values *C_p = 1.64 and C_{pk} = 1.52 are higher than 1.33 point, the turning process by production of flange shaft is currently sustainable and there is a place to continue in its further improvement.*

4. CONCLUSION

Cp and Cpk are called process capability. Pp and Ppk are called process performance. In both cases we want to try to verify if the process can meet to meet customer CTQs . The turning process capability study by production of flange shaft verify an ability of the process to meet the defined requirements of product quality from customer´s side. The results of process capability - the capability indexes C_p = 1.64 and C_{pk} = 1.52 are an

evidence, that the process is permanently able to provide products compliant with tolerance limits.
According to these obtained values maybe we can recommend to narrowing of tolerance limits. After that there is an assumption that C_p and C_{pk} indexes can achieve almost identical values.
Control charts are suitable graphic method for probabilistic hypotheses testing. Based on these data, we accede to capability indexes calculation and also process capability evaluation. This information is a signal for the organisation for quality improvement and an evidence for the customer about stable production conditions.
For the future, the company should evaluate not only the preliminary process capability (as usually), but also establish the long term process capability evaluation. It is also appropriate to use only the statistical software for MSA, control charts, process capability etc. evaluation. Managers often drew the control charts with the pencil on the paper, calculate the indexes by calculator and after the he transferred these data to the computer. Using the statistical software can help with time savings and also the manager can be sure, that his results are right.

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