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PROCESS CAPABILITY STUDY BY PRODUCTION OF HYDRAULIC COMPONENTS

Abstract. This study focuses on ISO evaluation of process capability in the production of hydraulic components according to ISO 9001: 2008 Quality Management Systems requirements. Statistical process control is analysed on the basis of normality and stability of the process, and cutting process capability indices C_p and C_{pk} are calculated. The values obtained for indices are $C_p = 3.29$ and $C_{pk} = 0.73$. Therefore, it can be considered the process is capable.
Keywords: serial production, control charts, process capability, C_p and C_{pk} indices, process stability.

BADANIE ZDOLNOŚCI JAKOŚCIOWEJ PROCESU PRODUKCJI ELEMENTÓW HYDRAULICZNYCH

Streszczenie. Przedstawione badania dotyczą analizy zdolności jakościowej procesu produkcji elementów hydraulicznych zgodnie z normą ISO 9001: 2008 (Wymagania dotyczące systemów zarządzania jakością). Statystyczna kontrola procesu cięcia jest analizowana na podstawie rozkładu normalnego i analizy zdolności jakościowej procesu w oparciu o współczynniki C_p i C_{pk}. Uzyskane wyniki *współczynników* wynoszą odpowiednio $C_p = 3{,}29$ i $C_{pk} = 0{,}73$. W oparciu o uzyskane wyniki możemy uznać, że proces jest statystycznie uregulowany, ale przesunięty względem wartości nominalnej.
Słowa kluczowe: produkcji seryjna, karty kontrolne, zdolność jakościowa procesu, współczynniki C_p, C_{pk}, uregulowanie statystyczne procesu.

Introduction

The manufacturing organization is situated in Middle Slovakia and deals with the manufacturing of hydraulic and electronic components. It was discovered by the observations that qualitative errors arise in the manufacturing process. Therefore, it was necessary to implement the statistical control into the manufacturing process, and the chosen product was one component on axial hydroelectric generator, presented in Figure 1.

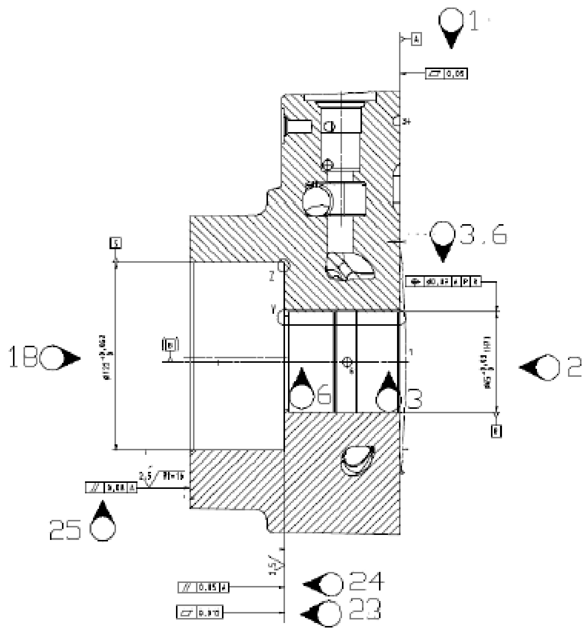

Fig. 1. Cut through the component / component technical documentation (own source)

In practice, the important group of statistic methods is formed by analyzing of qualification of measures, production equipment and qualification of process. From statistic methods mentioned above the mostly used is one examination of process qualification. By the term „process qualification" we mean ability of the process to observe when technical parameters required value and tolerance limits. By finding of the process capability we can isolate estimate process capability (before starting the production) and permanent process capability. The main distinction is in time span, in quantity of obtained values and in the form of obtaining. These information present the fact for the customer about expected fulfilment his requirements.

We can say that the process is capable if C_p a C_{pk} indicates are higher than 1.33.

Between input data belong:

- definitive conditions series production,
- convenient and able measuring equipment accuracy,
- able production facilities,
- statistically encompassment process through the quality control charts,
- test on assumed division,
- technical and others specification correctly expressive customer's request.

Materials and methods

Description of the process:
Operating step: Drilling
Mark: mean of the hole
Rating value: 65.000 +0.030 mm
Lower Specification limit (LSL): 65.000 mm
Upper Specification limit (USL): 65.030 mm
Check centre: Zeiss
Volume of subgroup: N = 115
Measure of subgroup: n = 5
Interval of taking: every 30 minutes
Number of subgroups: k = 23

Criteria for evaluation competence are Cp and Cpk indexes. From specification products as critical point of viewer we consider the mean of the hole 65.000 +0.030 mm. This is the key sign for the component. The key sign in the company is defined as a sign, where the expected normal variability of the process influences the product´s functioning and customer´s satisfaction. We suppose normal division of the process and suitability of applications partitions we appreciate through the histogram. For regulation of the drilling process we shall use regulating schema control chart for average and span ($\overline{X}$, R).

Calculation of specification limits

Plotting and evaluation of control charts for average $\overline{X}$ and range *R*

Values calculated are used for plotting the control charts for average and range, which are analysed and evaluated after that. The drilling process is statistically controlled only when its variability is caused by random causes. If the drilling process is affected by definable causes, it is necessary to determine the reason of negative effects and correct measure witch leads leading to the achievement of process stability.

average range in subgroups

$$\overline{X_i} = \frac{1}{n}\sum_{j=1}^{n} X_{ij} \tag{1}$$

i = 1, 2 ....k and j = 1, 2 ...n,
X_{ij} – measured value in i- subgroups
j –serial number of measured value in i- subgroups
k –number of subgroups
n –file size

span in subgroups

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

i = 1, 2 ... k and j = 1, 2 ...n
MAX (X_{ij}) and MIN(X_{ij}) is maximum and minimum value in i-th subgroup.

average of process:

$$\overline{\overline{X}} = \frac{1}{k}\sum_{i=1}^{k} \overline{X_i} \tag{3}$$

$\overline{X_i}$ - average of j – th subgroup

Average of span:

$$\overline{R} = \frac{1}{k}\sum_{i=1}^{k} R_i \tag{4}$$

$R_i X_i$ are spans and averages in *i*-th subgroups (*i*=1, 2, ...*k*). $\overline{R}$ and $\overline{\overline{X}}$ in quality control charts are central lines (*CL*).

Calculation of specification limits:

$$UCL_R = D_4 \cdot \overline{R} \tag{5}$$

$$LCL_R = D_3 \cdot \overline{R} \tag{6}$$

$$UCL_{\overline{X}} = \overline{\overline{X}} + A_2 \cdot \overline{R} \tag{7}$$

$$LCL_{\overline{X}} = \overline{\overline{X}} - A_2 \cdot \overline{R} \tag{8}$$

D_4 ,D_3 and A_2 are constants moving in dependence on volume of subgroups *n* in our case n = 5: $D_3 = 0.000$, $D_4 = 2.114$, $A_2 = 0.577$.

Qualification of drilling process

$$C_p = \frac{USL - LSL}{6\hat{\sigma}} = \frac{T}{6\hat{\sigma}} \quad (9)$$

$$C_{PK} = \frac{USL - \overline{\overline{X}}}{3\hat{\sigma}} \quad (10)$$

$$C_{PK} = \frac{\overline{\overline{X}} - LSL}{3\hat{\sigma}} \quad (11)$$

USL – Upper Specification limit
LSL – Lower Specification limit

Production process capability
It is possible to evaluate the drilling process capability if the following conditions are met:
- process is statistically controlled (stable),
- measured values of the process are characterised by normal distribution,
- technical and other specifications are defined by customer requirements,
- nominal value is located in the centre of tolerance range.

Values of drilling process capability are expressed by the capability indices C_p and C_{pk}. Before starting to calculate the process capability indices, process standard deviation needsw to be estimated:

- estimation of process standard deviation:

$$\hat{\sigma} = \frac{\overline{R}}{d_2} \quad (12)$$

where:
$\overline{R}$ – average range in subgroups,
d_2 – constant of a central line, changing according to subgroup size from 2 to 25, the value $d_2 = 2.326$ corresponds to $n = 5$.

The resulting drilling process indices must meet the previously specified condition ($C_p \geq 1.33$ and $C_{pk} \geq 1.33$), which can be corrected by the given organization according to internal requirements (cannot be lower).

Results and discussion

In the drilling process we obtained by measuring 115 values, which were divided into 23 sub-groups with a range of 5 products in one sub-group (Tab. 1).

Table. 1. Measured data (own source)

Subgroup	Product				
1	65,0294	65,0284	65,0273	65,0274	65,0278
2	65,0285	65,0294	65,0284	65,0268	65,0290
3	65,0280	65,0289	65,0264	65,0271	65,0274
4	65,0270	65,0286	65,0276	65,0264	65,0249
5	65,0260	65,0267	65,0254	65,0247	65,0254
6	65,0252	65,0254	65,0248	65,0241	65,0239
7	65,0235	65,0243	65,0248	65,0253	65,0249
8	65,0252	65,0250	65,0259	65,0260	65,0260
9	65,0262	65,0252	65,0256	65,0251	65,0238
10	65,0255	65,0251	65,0243	65,0239	65,0284
11	65,0287	65,0260	65,0284	65,0285	65,0286
12	65,0280	65,0293	65,0289	65,0290	65,0261
13	65,0281	65,0287	65,0299	65,0276	65,0281
14	65,0256	65,0282	65,0240	65,0286	65,0299
15	65,0274	65,0290	65,0287	65,0295	65,0283
16	65,0284	65,0257	65,0290	65,0257	65,0284
17	65,0277	65,0283	65,0292	65,0289	65,0261
18	65,0276	65,0278	65,0291	65,0272	65,0273
19	65,0280	65,0291	65,0263	65,0250	65,0270
20	65,0280	65,0265	65,0266	65,0259	65,0287
21	65,0249	65,0261	65,0266	65,0260	65,0240
22	65,0259	65,0259	65,0261	65,0264	65,0264
23	65,0243	65,0244	65,0230	65,0264	65,0286

The measured values presented in the histogram show that the process isn´t in statistical control (Figure 2).

The dispersion of the process is very small comparing tolerance zones, but the whole process is shifted to the upper tolerance zone. Histogram has two top peaks, which are probably affected by tool changing. For a correction action it is necessary to move the process into the middle of tolerance zones.

For quality ($\overline{X}, R$) control charts were calculated central limits:

UCL_X= 65.02844 mm

LCL_X= 65.02522 mm

$\overline{\overline{X}}$ =65.02680 mm

UCL_R = 0.0059 mm

$\overline{R}$ =0.0028mm

Based on the calculated values there were plotted control charts for span R (Figure 3) and average $\overline{X}$ (Figure 4).

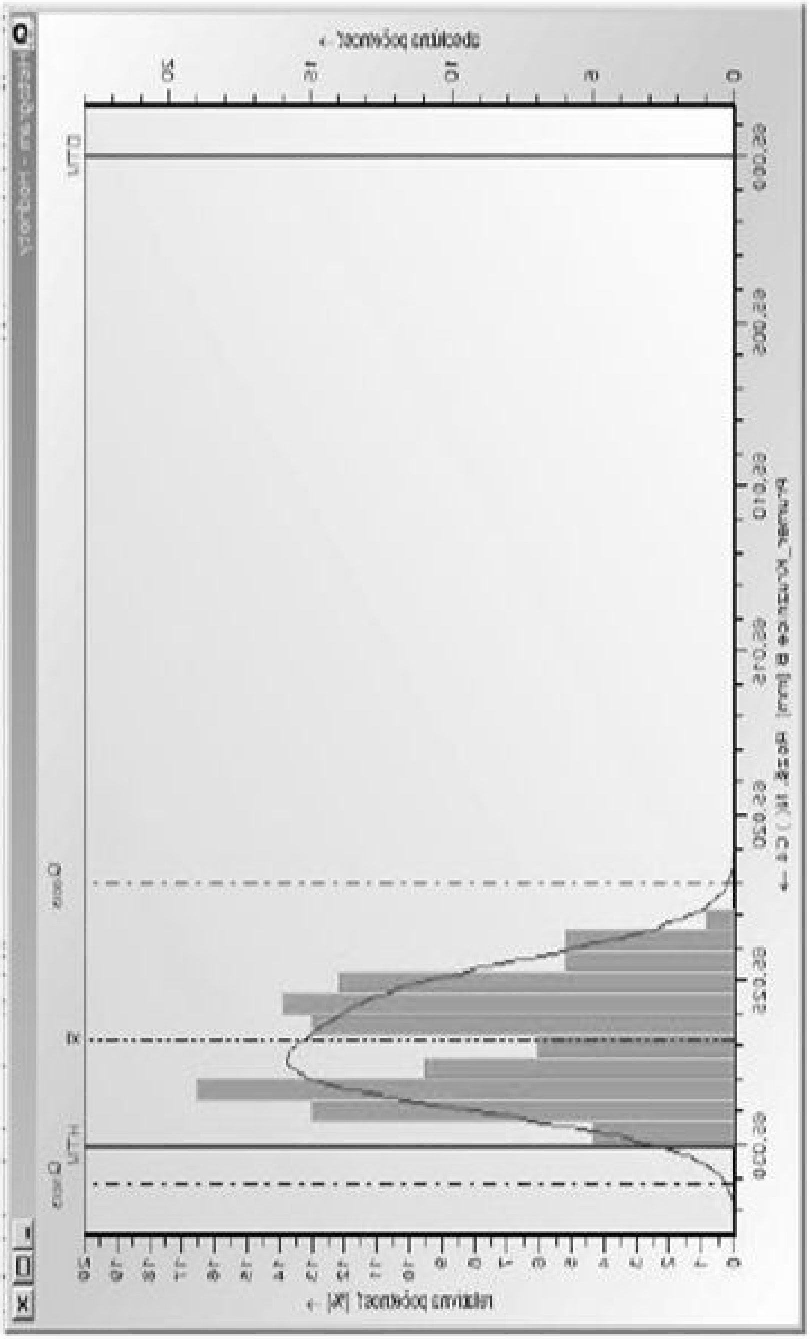

Fig. 2. Histogram of the measured data (own source)

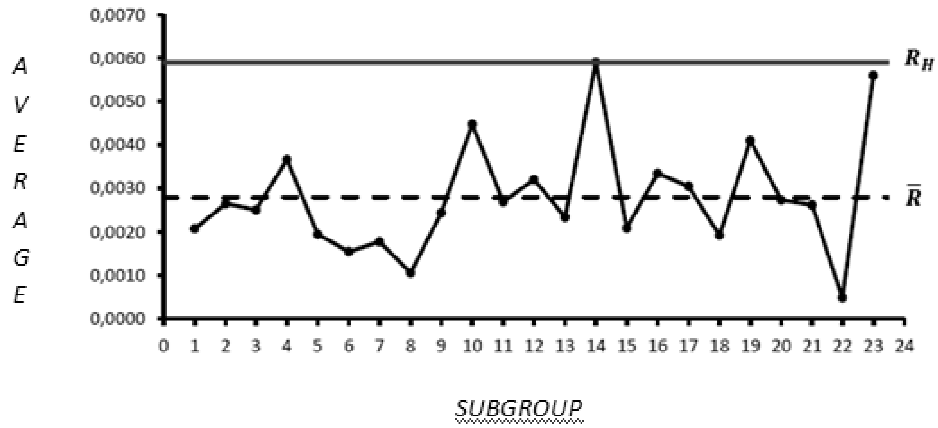

Fig. 3. Control chart for span R (own source)

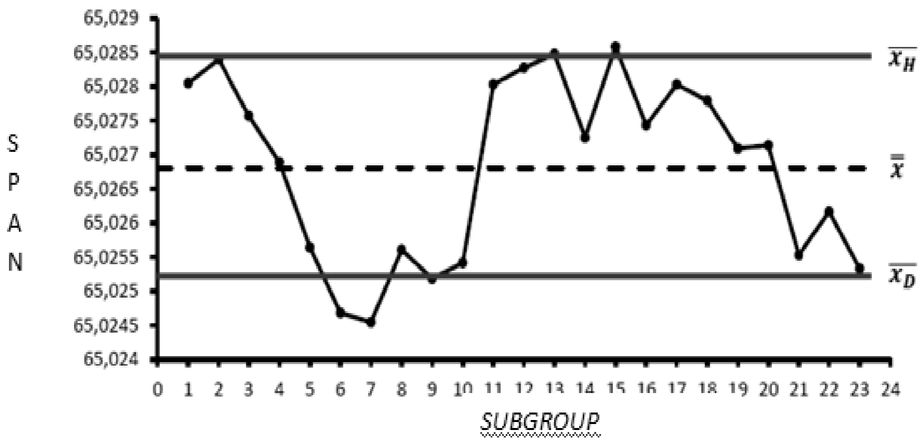

Fig. 4. Control chart for average $\overline{X}$ (own source)

As we can see in the Figure 3, each measured values in subgroups are within the control limits, only one is located on the upper control limit. In the Figure 4 is plotted control chart for average. We can see, that subgroups 6, 7 and 15 are located out of control limits and subgroups 9 and 13 are located on the control limits. So therefore we can consider this process unstable.

We also calculated the indices C_p and C_{pk}. The calculated values are $C_p = 3.29$ and $C_{pk} = 0.73$.

Based on these values, we can consider the drilling process unstable because the critical value is lower than 1.33 and therefore it is necessary to suggest the corrective actions.

Summary

The methods of statistical process control and evaluation of drilling process capability verify an inability of the process to meet the defined requirements of product quality. Drilling process is influenced by definable causes, therefore we should suggest the corrective actions. We calculated following values: the indices C_p = 3.29 and C_{pk} = 0.73. As the most important factor was given the tool – reamer. The reamer is used to hole making. This tool was produced on the upper level of the tolerance: +0.027 till 0.029. The reason was the durability. If the tool was worn-downed in some microns, it was still able to produce the required dimension. The inaccuracy of the tool ficture and of the machine spindle is main reason, that the reamer produce the dimension on the highest tolerance, in some cases out of tolerance.

Therefore it is necessary to produce the reamer with less nominal size about 0.01 mm.

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