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STATISTICAL PROCESS CONTROL IN AUTOMOTIVE INDUSTRY

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Organisations active in the market, regardless of the sphere of action, must constantly face pressures from an uncompromising competition. Therefore, if organisations wish to be successful in the market and constantly move forward, they must draw attention to the quality of products in the market. Statistical process control is the implementation of such statistical methods through which the production process is regulated and controlled to ensure the production of the highest possible amount of products that comply with requirements imposed on them.

Keywords: quality, statistical process control, capability, door panel

An important aspect of the production process is a continued stability that can be achieved by regulation. To analyse the process means in particular to examine the factors affecting the process, to classify them according to their relevance, and to control them so as to achieve a stable and desired state. The capability analysis of measures, production equipment and process is active in the application, development and permanent improvement of quality system effectiveness. Process capability is the most used examination (Prístavka and Hrubec, 2009). According to the analysis of production equipment and appropriateness of production, we try to understand the current classification of effects that are conditional on production equipment and have a decisive influence on the production process during production (Oakland, 2003). Statistical process control is a primary tool to analyse the process of evaluation and improvement (Keller, 2011). Statistical control is used to reduce the occurrence of unacceptable events, which are an important parameter of a FMEA method for reducing risk (Bujna and Prístavka, 2012; Bujna et al., 2012). One of the basic tools of quality management in a number of organisations is a quality management system according to standards set by ISO 9000 (Prístavka et al., 2011).

Material and methods

Capability of production equipment

Before serial production, it is necessary to determine the capability of production equipment, on which the production process is running. The aim is to see that production takes place in familiar patterns and that the machine is capable of production within required tolerances. The capability of production equipment is evaluated using the indices of capability C_m and C_{mk} , where C_m indicates variance and C_{mk} process position. One of the basic requirements for determining the capability of production equipment is to specify the stability of measured values. Production conditions, an efficient measuring device, and process in statistical control are the primary conditions which are used to examine the process capability (Prístavka et al., 2007).

Stability

Before serial production, it is necessary to take at least fifty samples of products, from which subgroups with a minimum size of $n = 5$ are created. For the stability test, the mean $\bar{X}_i$ and standard deviation s_i are calculated for each subgroup (Hrubec, 2001).

The mean of attribute in the subgroup is calculated using the following formula:

$$\bar{X}_i = \frac{1}{n} \sum_{j=1}^n X_{ij} \quad (1)$$

where:

- i – serial number
- j – serial number of the measured value
- k – number of subgroups
- n – subgroup size
- X_{ij} – measured value in the i -th subgroup
for $i = 1, 2, \dots, k$ and for $j = 1, 2, \dots, n$

The standard deviation of the subgroup is calculated by the following formula:

$$s_i = \sqrt{\frac{1}{n-1} \sum_{j=1}^n (X_{ij} - \bar{X}_i)^2} \quad (2)$$

– for $i = 1, 2, \dots, k$ and for $j = 1, 2, \dots, n$

The next step is to calculate the common mean:

$$\bar{\bar{X}} = \frac{1}{k} \sum_{i=1}^k \bar{X}_i \quad (3)$$

Average standard deviation $\bar{s}$:

$$\bar{s} = \frac{1}{k} \sum_{i=1}^k s_i \quad (4)$$

For process stability, it is necessary to determine the limits:

1. For mean:

- upper control limit UCL:

$$UCL_{\bar{X}} = \bar{\bar{X}} + 1.3 \cdot \bar{s} \geq \bar{X}_{\max} \quad (5)$$

- lower control limit LCL:

$$LCL_{\bar{X}} = \bar{\bar{X}} - 1.3 \cdot \bar{s} \leq \bar{X}_{\min} \quad (6)$$

2. For standard deviation:

$$UCL_s = 2.1 \cdot \bar{s} \geq s_{\max} \quad (7)$$

Calculation of machine capability index C_m and C_{mk}

In calculating the machine capability index, first we need to calculate the value of standard deviation:

$$\sigma_{N-1} = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (X_i - \bar{X}_N)^2} \quad (8)$$

where:

N – total number of measured values

$$\bar{X}_N = \frac{1}{N} \sum_{i=1}^N X_i \quad (9)$$

where:

$i = 1, 2, \dots, N$

X_i – i -th value of measured attribute

Calculation of production equipment capability C_m and C_{mk}

Calculation of machine capability index C_m :

$$C_m = \frac{UCL - LCL}{6 \cdot \sigma_{N-1}} = \frac{T}{6 \cdot \sigma_{N-1}} \quad (10)$$

where:

T – tolerance of attribute

UCL, LCL – upper and lower control limits

Corrected production equipment capability index C_{mk} :

$$C_{mk} = \frac{UCL - \bar{X}_N}{3 \cdot \sigma_{N-1}} \quad (11)$$

$$C_{mk} = \frac{\bar{X}_N - LCL}{3 \cdot \sigma_{N-1}} \quad (12)$$

The production equipment is capable when $C_m \geq 1.66$ and $C_{mk} \geq 1.67$ (Michálek, 2006). If the production equipment is capable, control charts are developed by measuring before determining the process capability (Hrubec, 2001).

Results and discussion

The aim of this work was to determine whether the production process of a door panel in pre-serial production is in statistical control. Equipment capability was examined in a spot ultrasonic welder. The monitored attribute was the deviation at the 'critical point' on the door panel. This door panel (interior) is installed in a new type of the Peugeot 208 automobile. For statistical calculations and graphical representation of results, we used the program Minitab 15. The nominal value of the measuring point is 1.5 mm with a tolerance of ± 2 mm.

After measuring the fifty values, we have calculated the mean value $\bar{X}_i$ according to Equation (1) and the standard deviation s_i for each subgroup (as shown in Table 1) according

Figure 1 Ultrasonic welding machine

to Equation (2). Then, the total mean $\bar{\bar{X}} = 1.12$ mm was calculated according to Equation (3) and the average standard deviation $\bar{s} = 0.1461$ mm from all subgroups according to Equation (4), which serve as central lines (CL) in control charts. The upper control limit $UCL = 1.3286$ mm and the lower control limit $LCL = 0.914$ mm were calculated according to Equations (5) and (6) for mean, and the upper control limit $UCL = 0.3053$ mm was calculated according to Equation (7) for standard deviation.

The control charts for mean and standard deviation indicate that none of the specified values exceeds the upper or lower control limit; there were no groupings or trends. Therefore, we can say that the process is in control.

A histogram displays the relative frequencies in individual intervals as uniformly distributed; most values

Figure 2 Door panel on a fixture

Table 1 Measured and calculated values

Subgroup number	Measured values in mm					in mm	in mm
	X_1	X_2	X_3	X_4	X_5		
1	1.18	1.15	1.20	1.09	1.30	1.18	0.0770
2	1.50	0.85	0.97	1.15	1.03	1.10	0.2484
3	1.13	1.07	1.25	1.18	1.27	1.18	0.0831
4	1.14	0.86	1.16	1.40	1.18	1.15	0.1921
5	0.96	1.23	0.99	0.94	1.13	1.05	0.1251
6	1.10	0.96	1.19	0.84	1.00	1.02	0.1339
7	1.17	0.89	1.39	1.08	1.42	1.19	0.2210
8	1.22	0.84	0.96	1.09	1.30	1.08	0.1871
9	1.12	1.06	1.24	1.17	1.26	1.17	0.0831
10	1.02	1.03	1.15	1.09	1.10	1.08	0.0536
						$\bar{X} = 1.12$	$\bar{s} = 0.1461$

Figure 4 Control chart for mean and standard deviation **Figure 5** Histogram **Figure 3** Indicating gauge Mitutoyo

occur around the mean, and the probability distribution curve is bell-shaped. Therefore, we can conclude that the process is subject to normal distribution.

The mean $\bar{X}_N = 1.12$ was calculated according to Equation (9), and the standard deviation $\sigma_{N-1} = 0.1517$ was determined according to Equation (8). After these calculations, we could proceed with calculating the process capability indices according to Equation (10) $C_m = 4.39$, according to Equation (11) $C_{mk} = 5.23$, and according to Equation (12) $C_{mk} = 3.56$. In case of C_{mk} we took into account the lower value. The condition $C_m \geq 1.66$ and $C_{mk} \geq 1.67$ was satisfied. Therefore, we can say that the production equipment is capable.

Conclusion

The automotive industry belongs to one of the largest industries, many world economies are dependent

on it, and within Slovakia it represents the largest part of gross domestic product. In this work, we are analysing the issue of production equipment capability, specifically the ultrasonic welder for welding the components of the door panel until its final appearance. The subject-matter of statistical examination was the critical point on the door panel, which is measured using an indicating gauge. After collecting fifty products from the process and performing the measurements, we continued with their statistical evaluation. Control charts revealed that the process is stable, the histogram confirmed a normal distribution, and the calculated indices $C_m = 4.39$ and $C_{mk} = 3.56$ demonstrated production equipment capability because the condition $C_m \geq 1.66$ and $C_{mk} \geq 1.67$ was met.

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