Chapter 4

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USING THE STATISTICAL TOOLS IN MACHINE´S CAPABILITY EVALUATION – PART 1

Abstract: As first as we are able to set up some apparature to process it is necessary to find up if this apparature is in progress of capability and if it is able to made produce in our demanded parameters. The main point of statistical evaluation lie on that variability of process can be on one cause – machine composition. Capability of measured apparature is assess by C_m and C_{mk} indicator. As the results showed, the pressing machine is not capable for injection, the index C_m=3,52 and C_{mk}=1,51, because the index C_{mk} is lower that value 1,67. Therefore it is necessary to apply the correction actions and after them check the machine´s capability again. After correction actions were calculated values of scrap index for finding if the pressing machine is capable to produce in demanded parameters. The scrap index was 0,728%, which is lower than one month before. So we can consider the machine as capable.

Key words: statistical tools, capability indexes, machine, production

4.1. Introduction

Monitoring capability of production or manufacturing machines is followed by issue of statistical control charts of a production process. Capability analysis means the ability to produce machines and process followed by specific requirements. The capability of production machines characters the ability to produce equipments meet required specifications.

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During the research, if the machine, which we used in the process is capable, measuring data collects in a short period . During that time, which may take a few minutes, others input (for example, material condition, service) remains constant. A relatively high quantity of pieces supposed to be measured and be recorded during one period. In the process needs to be used calibrating gaugers. Before data collection for an evaluation of a production facility, ensure stability system conditions. Obtained data must be followed by conditions of rating and stability process.

Therefore divide measured data into five artificial subgroups and after that start analysing the statistical stability by control chart. If the result is not positive, find out the reasons and take a corrective action until it reaches statistical stability. The capability index of production machine has symbols C_m, C_{mk}. Data collection points out the only variability of production machines. This is the reason why requirement for index C_m is stricter than for index C_{pk}. Production machine or equipment is capable only if the index C_{mk} is higher than 1.67.

4.2. Materials and methods

Working operation: injection molding
Character of quality: measuring point, this was defined by the customer on the injected part.

Nominal value:	0.00mm
Lower Tolerance limit (LTL):	-0.20mm
Upper Tolerance limit (UTL):	0.20mm
Gauge: a clock	
Produce machine: injection machine	ENGEL
Number of measurements:	50
Range of subgroups:	5

We devote this article to the statistical methods, which part is monitoring capability of injection machine Engel in the injection molding

produce process. We utilize statistical control charts for stability analysis. Capability of machine is analysed via capability index C_m and C_{mk}.

Measuring point on the injected part was measured by using a clock gauge. Naturally, a Gauger must have R&R study (capability of measurement system) before the analysis. In the next step of analysis, we determined normality of process with the help of Fischer test. We analysed the stability of injection molding process via Shewhart $\overline{X}$,R control charts.

Calculation of Control Limits:

Average value of characteristic in the subgroups:

$$\overline{X}_i = \frac{1}{n} \sum_{j=1}^{n} X_{ij} \qquad (4.1)$$

For $\quad i = 1, 2 \ .... k$ and $j = 1, 2 \ ...n$,

If: $\quad i$ – The serial number of the subgroups,

$\quad\quad j$ – The serial number of the measured values in the subgroup,

$\quad\quad k$ – The number of the subgroups,

$\quad\quad n$ – The number of measurements within a subgroup,

$\quad\quad X_{ij}$ – measured value in i-th subgroup.

And range in the subgroups:

$$R_i = MAX(X_{ij}) - MIN(X_{ij}) \qquad (4.2)$$

For $\quad i = 1, 2 \ ... \ k$ and $j = 1, 2 \ ...n$

If: $\quad MAX \ (X_{ij})$ a $MIN \ (X_{ij})$ are maximum and minimum value in the i-th subgroup.

The grand mean of all the individual subgroup averages is:

$$\overline{\overline{X}} = \frac{1}{k} \sum_{i=1}^{k} \overline{X}_i \qquad (4.3)$$

And we need also the average of the ranges for all subgroups:

$$\overline{R} = \frac{1}{k} \sum_{i=1}^{k} R_i \qquad (4.3)$$

Where R_i, X_i are ranges and averages into the i-th subgroups ($i=1, 2, ...k$). $\overline{R}$ and $\overline{\overline{X}}$ forms the central lines (CL) in the control charts. These lines are plotted like solid horizontal lines in the graph. For the monitoring of process stability is needed calculation of control limit (UCL and LCL)

Calculation of control limit:

$$UCL_R = D_4 . \overline{R} \qquad (4.5)$$

$$LCL_R = D_3 . \overline{R} \qquad (4.6)$$

$$UCL_{\overline{X}} = \overline{\overline{X}} + A_2 . \overline{R} \qquad (4.7)$$

$$LCL_{\overline{X}} = \overline{\overline{X}} - A_2 . \overline{R} \qquad (4.8)$$

Where D_4, D_3 and A_2 are constants, which are changed with the number of measurements within a subgroup n. In our situation, we have got n = 5 and values of constants: D_3 = 0.000, D_4 = 2.114, A_2 = 0.577. Upper Control Limit and Lower Control Limit are plotted like broken lines in the graph.

Machine capability index C_m is determined by the formula:

$$C_m = \frac{USL - LSL}{6.\sigma_{N-1}} = \frac{T}{6.\sigma_{N-1}} \qquad C_m \geq 1{,}66 \qquad (4.9)$$

Where: T – tolerance of quality character,
   USL, LSL – Upper and Lower Specific Limit.

And corrected machine capability index C_{mk}:

$$C_{mk} = \frac{USL - \overline{X}_N}{3.\sigma_{N-1}} \qquad (4.10)$$

$$C_{mk} = \frac{\overline{X}_N - LSL}{3.\sigma_{N-1}} \qquad C_{mk} \geq 1{,}67 \qquad (4.11)$$

Standard deviation:

$$\sigma_{N-1} = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}\left(X_i - \overline{X}_N\right)^2} \qquad (4.12)$$

Where: N – The total number of measured values

$\overline{X}_N$ - *Average value calculated from all measurements*:

$$\overline{X}_N = \frac{1}{N}\sum_{i=1}^{N} X_i \qquad (4.13)$$

Where: $i = 1, 2, ... N$

X_i – i-th value of measured character

4.3. Results and discussion

In the process of injection molding on machine ENGEL we obtained by measuring 50 values, which were divided into 10 sub-groups with a range of 5 products in one sub-group (Tab. 1).

Table 4.1. Measured data (own source)

Subgroup	Product				
	1	2	3	4	5
1	0.12	0.13	0.14	0.12	0.11
2	0.14	0.12	0.07	0.09	0.10
3	0.09	0.12	0.13	0.10	0.11
4	0.10	0.12	0.12	0.10	0.11
5	0.14	0.08	0.10	0.12	0.09
6	0.13	0.10	0.12	0.14	0.13
7	0.08	0.11	0.09	0.10	0.08
8	0.10	0.16	0.15	0.15	0.11
9	0.11	0.15	0.13	0.12	0.11
10	0.10	0.12	0.14	0.09	0.10

Fisher test, which belongs to the parametric test, used to verify the normality of measured data. The test demonstrated the normality of the set of measured values.

Then we could proceed into calculating the regulatory borders and into constructing control charts ($\overline{X}$, R).

Calculated characteristics $\overline{X}$ and R apply in control charts. Regulatory limits and central lines were further drawn into the control charts.

For ($\overline{X}$, R) control chart, control limits are as follows:

UCL_X = 0.139188mm UCL_R = 0.093016mm
LCL_X = 0.088412mm LCL_R = not determined
$\overline{\overline{x}}$ = 0.1138 $\overline{R}$ = 0.044

Fig. 4.1 shows constructed control chart for the average and Fig. 4.2 shows constructed control chart for variation margin R.
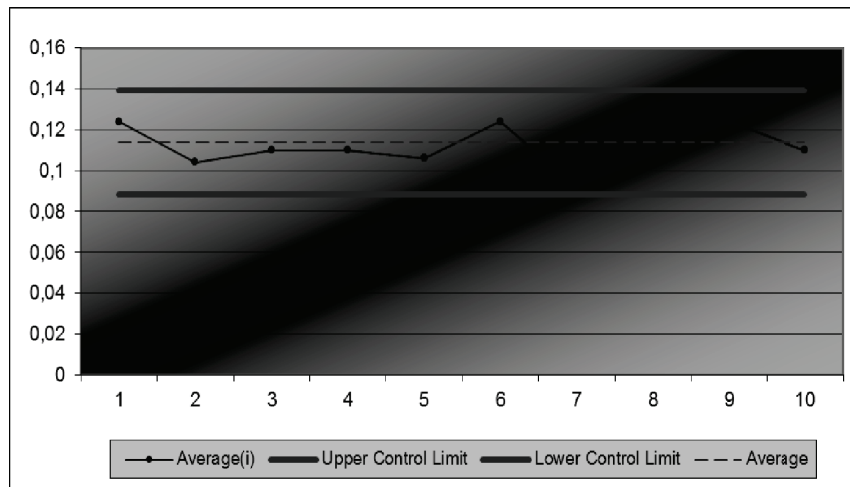

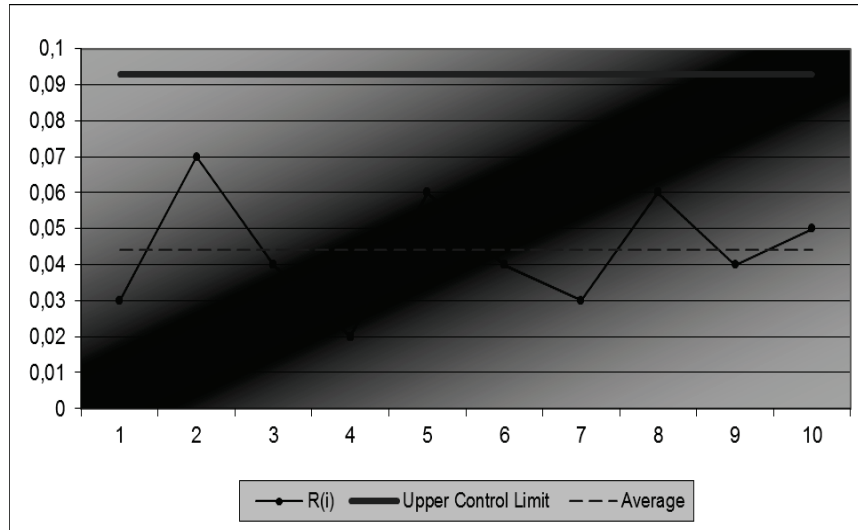***Fig. 4.1. Control chart for average.***

Source: own study

Fig. 4.2. Control chart for variation margin

Source: own study

Using a control chart we came to the conclusion that the set of data complies with statistical stability. This means the process is affected only by random effects and therefore we can proceed into calculating the capability indexes of production equipment C_m and C_{mk}.

$$C_m = 3.524242 \qquad\qquad C_{mk} = 1.518948$$

Capability index C_{mk} injection molding machine is smaller than 1.67, so it follows that the ENGEL injection machine is not capable of producing in the process of injection moldings according to customer requirements. Therefore it is necessary to address to the corrective and preventive actions to detect the cause of disqualification production facility and then it is necessary to take corrective actions, which lead to the reintroduction of production equipment to a competent state.

4.4. Summary

Monitoring of capability of injection molding machine ENGEL in process injection molding proved, then production machine is not capable. This machine does not produce products, which discharges to the quality criteria of customers.

The results of capability study, $C_m = 3.52$ and $C_{mk} = 1.51$ are a fact of the incapability of the machine. Since the critic capability index must be 1.67 in the automotive industry. In this situation, we must identify the causes of machine incapability and improve the process. We need to take corrective and preventive interventions, which improve the machine on the better level. The machine must be capable and produce the products, which satisfy to the requirement of customers. We are discussed to the issue of increasing production machine in capable condition in the next article – Part 2.

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