Analysis of the possibility of production processes based on modern methods

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Abstract. Comprehensive measures are being implemented aimed at ensuring the comprehensive integration of production enterprises into world markets, increasing the quality and competitiveness of manufactured products, improving the quality management system and product production processes. This article discusses the main essence of the analysis of production processes at engineering enterprises based on statistical methods and the possibility of improving the effectiveness and efficiency of processes based on the fulfillment of the requirements for them. Statistical control of processes by monitoring the description of processes and products, focusing the possibility of processes on the creation of a quality product with a uniform demand, identifies the working procedure for managing the processes of constant production technology and allows to increase the efficiency of the process possibility. Statistical process control is not about checking whether parts are in good condition or not, but about anticipating and trying to prevent the production of poor quality parts. This is done by using control charts as a predictive tool to identify potential inconsistencies. Keywords: Statistical Process Control, IATF 16949, control chart, prevention, defect, nonconformity.

1 Introduction

In the world today, in the modern conditions of the economy, the global system of product production and delivery requires the effective use of methods and tools of the modern quality management system, which allows to improve the quality and efficiency of production processes, to reduce costs in the supply chain. Fulfillment of the requirements in this regard makes it possible to reduce inconsistencies in the production chain and achieve sustainable development rates by focusing all attention on the prevention of defects rather than finding them [1-3].

As a result of economic reforms in Uzbekistan, comprehensive measures are being implemented aimed at ensuring the comprehensive integration of production enterprises into world markets, increasing the quality and competitiveness of manufactured products, improving the quality management system and product production processes [4, 5]. However, the copying of quality management methods and mechanisms by many local enterprises, without taking into account the existing real situation, without deep scientific analysis, leads to serious inefficiency of their economic and social situation.

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Modern management researchers [5-9] currently believe that the quality management system should be considered not only as a subsystem of the enterprise in relation to quality, but as a whole system of internal management focused on product quality criteria of activity. The quality management system should become an enterprise management system that helps to achieve, maintain and continuously improve the expectations and satisfaction of consumers and other interested parties [10-12].

In this study, based on the international standard IATF 16949, the ways of improving the quality of products and processes based on the statistical control of processes in machine-building enterprises, the main changes, their importance, and what should be done to comply with them were considered.

2 Materials and Methods

Monitoring of the description of processes and products in production enterprises, statistical management of process possibilities, management of continuous production technology processes have been studied to a certain extent in the scientific researches of foreign scientists and modern researchers.

Analytical methods, process approach, multidimensional data analysis, statistical methods of process management, information models of quality management were used in the research process.

"Statistical Process Control - SPC" (statistical control of processes) is used in the automotive industry for process control [10], this method was developed in 1990 by the American Automotive Industry Standardization Group (AIAG), and "Daimler Chrysler", "Ford Motor Company" and have been reviewed and approved by General Motors experts and required by their component suppliers.

According to the requirements of the international standard IATF 16949:2016, the enterprise must ensure compliance with the product requirements approved by the consumer with the possibility of production processes and the results of its function. In this case, the organization process flow card, PFMEA analysis and control plan, measurement methods, selection plan, acceptance criteria, actual measurement and/or test values, variability results records, implementation plan and grading process when the acceptance criteria are not met, take into account aspects of the SPC implementation must verify the achievement [4].

The standards of the ISO 9000 group consider statistical methods as a mandatory and effective tool in determining the requirements for the quality system and ensuring quality.

3 Results and Discussion

In the production process, let's not strictly adhere to the requirements of the technology, it is difficult to get the intended quality indicator due to the influence of many factors. This leads to the need to analyze the state of processes with the possibility of evaluating the indicators.

The task of statistical management of processes is to ensure that the processes are adopted and maintained at a stable level, and that products and services conform to the established requirements [5]. In this case, control cards are used as the main tool of statistical control of processes.

It is difficult to imagine modern production enterprises without automation processes. Since Statistical Process Control is a statistical method, time consumption can be reduced by implementing a computer program. The International Automotive Quality Management System Standard IATF 16949:2016 sets requirements for SPC analyzes for critical and specific specifications defined in the PFMEA and control plan.

According to the requirements of the international standard IATF 16949:2016, the Organization should verify the feasibility of all new projects (taking into account the flow of assembly and production processes) and, in order to manage additional output results, study the output results together with special specifications [11-15].

For some manufacturing processes, process capability may not demonstrate product compliance. For such processes, alternative (quality control card) methods are used to demonstrate product batch conformity.

The organization must ensure compliance with the requirements of details approved by the consumer with the possibility of production processes and the results of its task (function). Accordingly, the organization should verify the implementation of the process flow chart, PFMEA analysis and management plan, taking into account the following aspects:

a) measurement methods;
c) selection plan;
c) acceptance criteria;
d) notes on the results of variation of measurement and/or test values obtained in practice;
e) implementation plan and grading process when acceptance criteria are not met.

An implementation plan must be in place for specifications identified in the organization's management plan and assessed for compliance with specifications that are not satisfactory in terms of feasibility or sustainability. Such an implementation plan should include 100% product verification, if necessary.

The task of statistical process control is to maintain and maintain processes in a favorable and stable (stable) state, and to guarantee the conformity of a product or service to demand.

In the implementation of SPC, the important characteristics of the product are determined by the technology department or, in agreement with the requirements set by the customer or the departments responsible for the processes, among the indicators of their characteristics, which are considered important for statistical control, they are included in the control plan as important characteristics, and the control card selects them for control.

On the basis of the control cards established in the control (S/R) plan, important descriptions of products and statistical control or monitoring of processes are carried out in agreement with the competent departments, and the control cards are selected as follows (Table 1).

Table 1. Selection of control cards.

Indicator types	**Control card**	**Scope of application**	**Comments**
Quantitative results	**(X – R)** average	(X - R) average cards - are used in the control of the characteristics of the output of the production process, that is, the average quantity and volume are determined. (Physical quantities: length, mass, time, strength, content, etc.). The data is obtained from the average value of 3 or 5 samples of the output results of the steady process (For example, coating thickness of the control coating of 3 selected bodies from painting in each shift or other specific quantities).	- shaft diameter changes; - decrease in tensile strength; - taking into account electricity consumption and others
	X	It is used if an indicator is controlled during the production process.	-alcohol concentration chemical concentration; - determination of pH of a chemical solution; - temperature control.
Quantitative results	**Me - R**	Median cards are used for odd-numbered sample groups of 10 or fewer, and even-numbered samples have medians—mean values in the middle of the range.	N/A

	L - S	The mean range (L or X) and standard deviation (S) cards are considered very easy to use in small bounded quantities, that is, sorted data (especially when the quantity is less than 9). The deviation from the standard deviation of the sorts is an indicator of the change of the S-process of great importance, and it is especially convenient to use it in multiquantity sorts.	Usually, the S-card is used with the R-card, and it should be applied mainly to the values obtained from high-precision measurements with a large amount of sorting and, as much as possible, unaltered.
Qualitative (alternative) results	**np**	np is the number of non-conformities in the controlled batch. The number of samples (range) for control should be within a homogeneous interval. The periodicity of the selections should be the same when comparing the backward communication system and production. It is necessary to give the opportunity to identify several inconsistencies in each part of the number of selections.	The p and np- control cards are used for alternative results for which no default value is given. For example, when inspecting 1,000 finished cars in each of 25 groups, determining the number and percentage of defects in them.
	p	p - the percentage of non-conforming products in the controlled selections is determined on the control card. This should be a sample of not less than 75 samples taken twice daily, showing the percentage of defective products in each sample. The product is applied to a group of hourly and daily selections during production.	
Qualitative (alternative) results	**c**	c – is used to identify unusual problems rather than typical inconsistencies in the sample from the control chart. It should contain previous information.	The product is being prepared by the process of stamps, 10 of every 100 pieces of products are controlled based on the requirement, thereby determining the number of scum (zausenets) formed during shaping, thereby eliminating the scum-forming environment.
	u	u – is used to determine the number of defects per product in each sample on the card. The number of non-conformities is calculated by the ratio of the number of products. When calculating the control limits, the number of samples does not have to be the same as the other samples, but their limit is greater or less than 25% to facilitate the calculation process.	In the weekly IQS, 15 (6 Nexia, 6 Spark and 3 Damas) cars are audited by the eyes of the buyer, and the number of defects corresponding to one product is determined.

The use of statistical methods helps to understand the variability of quality indicators and helps to increase the effectiveness and efficiency of decisions.

The process of implementing statistical methods and statistical control includes the following steps shown in Figure 1.

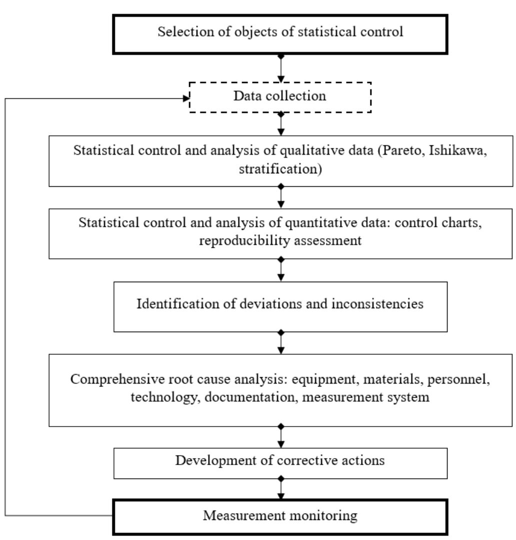

Fig. 1. Statistical control implementation process.

A special program was prepared for SPC analysis using the "Statistical Process Control" manual (Figure 2). The measurements were carried out during the production of the side part of the car tire at the "First Rubber Industry Plant" LLC.

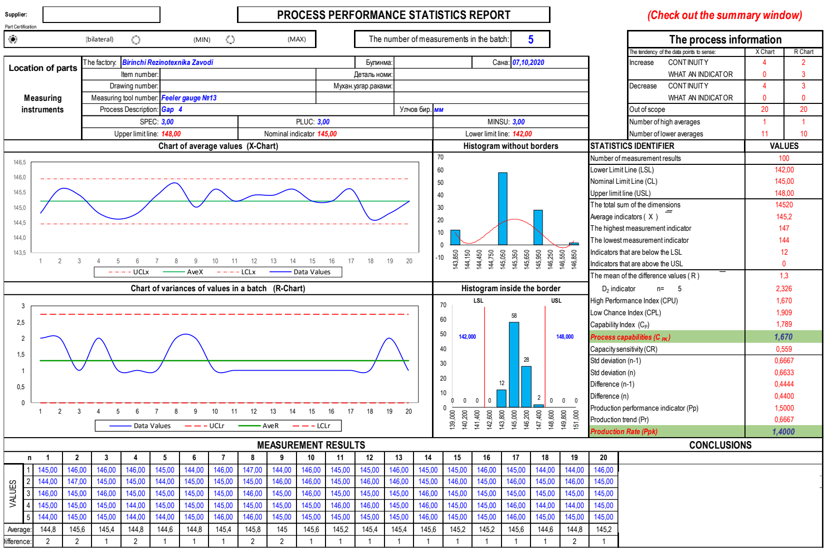

Fig. 2. SPC analysis report.

When performing the SPC analysis, the group size was selected based on the selection, which included 20 groups with more than 100 individual values. Measurements were made by the responsible employee and operators. The obtained values were entered into the values section of the measurement results window of the specially prepared program (Table 2).

Table 2. Measurement results.

n		1	2	3	4	5	6	7	8	9	10
Values	1	145	146	146	146	145	144	146	147	144	146
	2	144	147	145	145	144	145	145	145	146	146
	3	146	145	146	145	145	145	145	146	145	146
	4	145	145	145	144	145	145	145	145	145	145
	5	144	145	145	144	144	145	146	146	145	145
Average:		144.8	145.6	145.4	144.8	144.6	144.8	145.4	145.8	145	145.6
Difference:		2	2	1	2	1	1	1	2	2	1
n		**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Values	1	145	145	146	145	145	146	145	144	144	146
	2	145	146	146	145	146	145	146	145	146	145
	3	145	145	145	146	145	145	145	145	145	145
	4	146	146	145	146	145	145	146	144	144	145
	5	145	145	145	146	145	145	146	145	145	145
Average:		145.2	145.4	145.4	145.6	145.2	145.2	145.6	144.6	144.8	145.2
Difference:		1	1	1	1	1	1	1	1	2	1

For statistical processing of data, initially, the values of X average and R standard deviation are determined using the following formulas:

$$\overline{X} = \frac{X_1+X_2+...+X_n}{n}; \quad (1)$$

$$R = X_{large} + X_{small} \quad (2)$$

Where, $X_1 + X_2 + ... + X_n$ – individual values in a group, n – group size.

Control limits are determined first for the standard deviation map and then for the mean map. To calculate the initial period of the study and the control limits, the average value of the range and the average value of the X process are found using the following formulas:

$$\overline{R} = \frac{R_1+R_2+...+R_k}{k}; \quad (3)$$

$$\overline{\overline{X}} = \frac{\overline{X}_1+\overline{X}_2+...+\overline{X}_k}{k}; \quad (4)$$

Where, k – individual values in a group,

R_1 and $\overline{X}_1$– standard deviation and mean for the first group,

R_2 and $\overline{X}_2$– standard deviation and mean for the second group.

The upper and lower limits of the standard deviation and the average of the quantitative results of the control maps were determined using the following formulas:

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

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

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

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

Where, $D_3, D_4,$ and A_2 – coefficients depending on the (n) size of the group (obtained from the value of the F-Fisher-Snedekor distribution).

$D_4\overline{R}$ – R- the upper limit of the map is found by multiplying the middle of the hole by the coefficient D_4, that is, it represents the value of R - the upper line of the card;

$D_3\overline{R}$ – the lower limit of the R-card is found by multiplying the middle of the lap by the coefficient D_3, that is, it represents the value of the lower line of the R-card.

Using formulas 4, 7 and 8, we develop an X map for average values (Figure 3).

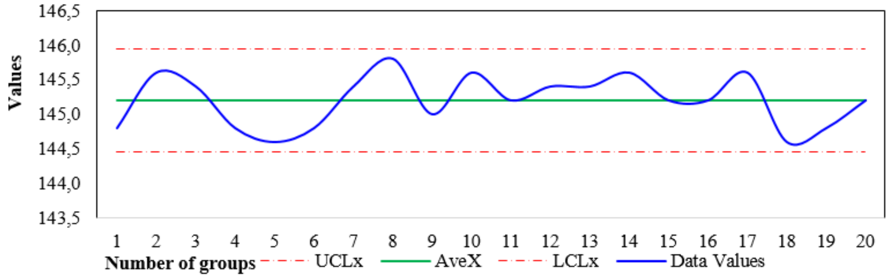

Fig. 3. Chart of average values (X-map).

Using formulas 3, 5 and 6, we develop an R map for the difference of values (Figure 4).

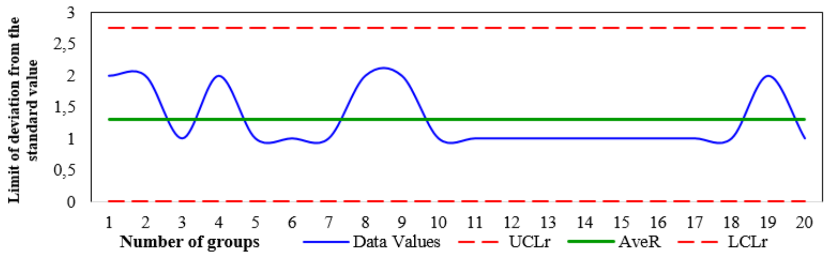

Fig. 4. Chart of differences of values (R-map).

The purpose of the process management system is to obtain statistical information on the specific causes of variation. Bringing the process to a state of statistical control based on the elimination of the cause of special variability. If the process is in a state of statistical control, the quality of the product can be predicted and the process will satisfy the requirements of the established regulatory document [16, 17].

Processability - identifies complete changes associated with common causes, i.e. all special causes have been eliminated. Process capability - indicates that the process is in a state of statistical control. It can be said that the management of $\bar{X}$ and R card consists of identifying, analyzing, correcting and preventing the occurrence of special causes, and then determining the possibility of the process.

C_p reproducibility and P_p serviceability indices indicate process variability in relation to technical requirements and are determined using the following formulas:

$$C_p = \frac{UCL-LCL}{6\hat{\sigma}_I}; \tag{9}$$

$$P_p = \frac{UCL-LCL}{6\hat{\sigma}_T}; \tag{10}$$

Where, $\hat{\sigma}$ - process standard deviation estimate of nested groups.

$\hat{\sigma}_I$ is determined using the following formula:

$$\hat{\sigma}_I = \frac{\bar{R}}{d_2} \tag{11}$$

Where, $\bar{R}$ – average range of subgroups (for periods when the process range is in the controlled state); d_2 – coefficient (taken from the table of coefficients for calculating the control limit).

The reproducibility indices C_{pk} and P_{pk} indicate the location and variability of the process within the limit of admissibility (tolerance) in relation to technical requirements and are determined using the following formulas:

$$C_{pk} = \frac{UCL-\bar{\bar{X}}}{3\hat{\sigma}_I} \text{ and } \frac{\bar{\bar{X}}-LCL}{3\hat{\sigma}_I}; \tag{12}$$

$$P_{pk} = \frac{UCL-\bar{\bar{X}}}{3\hat{\sigma}_T} \text{ and } \frac{\bar{\bar{X}}-LCL}{3\hat{\sigma}_T}; \tag{13}$$

Repeatability is determined for stable processes – CR. PR is determined for processes where the stability of validity coefficients has not been confirmed:

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$$CR = \frac{1}{C_p} = \frac{6\hat{\sigma}_I}{UCL-LCL}; \quad (14)$$

$$PR = \frac{1}{P_p} = \frac{6\hat{\sigma}_T}{UCL-LCL}; \quad (15)$$

General process capability status - process capability PCI (C_p) is determined by the index:
If PCI < 1, process capabilities are unacceptable;
If PCI = 1, the process is at the required capacity limit;
If PCI > 1, the process is at the requested capacity;
PCI = 1.33 is the current minimum acceptable value.
The general process possibility – (PCI) Cp (9) formula or C_{pk} index is determined by the following formula:

$$C_{pk} = (1-k)C_p; \quad (16)$$

$$k = \frac{2(X_{average}-N)}{(UCL-LCL)}; \quad (17)$$

where UCL is the upper bound; LCL-lower limit; N-permissibility scale average.
The following result was obtained when the possibility of processes was analyzed using the above formulas (Table 3).

Table 3. SPC analysis results.

Statistics ID	Values	Statistics ID	Values
Number of measurement results	100	High capacity index (CPU)	1.670
Lower Limit Line (LSL)	142.00	Index of the lower possibility (CPL)	1.909
Nominal Limit Line (CL)	145.00	Capability index (C_P)	1.789
Upper limit line (USL)	148.00	Process options (C_{PK})	1.670
The total sum of dimensions	14520	Impressive capabilities (CR)	0.559
Average indicators ($\overline{\overline{X}}$)	145.2	The STD deviation (n-1)	0.6667
The highest measurement indicator	147	The STD deviation (n)	0.6633
The lowest measurement indicator	144	Difference (n-1)	0.4444
Indicators lower than LSL	12	Difference (n)	0.4400
Indicators higher than USL	0	Production indicator (Pp)	1.5000
Average of different values ($\overline{\overline{R}}$)	1.3	Production trend (PR)	0.6667
D_2 indicator n=5	2.326	Production indicator (Ppk)	1.4000

$C_{pk} \geq 1.67$ process capability is excellent;
$1.33 \geq C_{pk} \leq 1.67$ process possibility is good;
$1.33 < C_{pk}$ process option is unsatisfactory;
$C_p > 1.33$ process possibility is good;
$1 < C_p < 1.33$ process capability is satisfactory;
$C_p < 1.33$ process option is unsatisfactory.

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A 6-sigma distribution of values and a process capability C_{pk} greater than 1.67 and a production P_{pk} greater than 1.33 indicate that the process capability is high.

4 Conclusions

Statistical control of processes by monitoring the description of processes and products, focusing the possibility of processes on the creation of a quality product with a uniform demand, identifies the working procedure for managing the processes of constant production technology and allows to increase the efficiency of the process possibility.

Statistical process control is not about checking whether parts are in good condition or not, but about anticipating and trying to prevent the production of poor quality parts. This is done by using control charts as a predictive tool to identify potential inconsistencies.

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