Applying the Six Sigma Methodology

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Abstract. This article describes the application of the Six Sigma Methodology on the example of the production process of microassemblies. The amount of sigma is calculated for the main indicator of the quality of microassemblies, which indicates their high defectiveness. The causes of the occurrence of defects are determined and corrective actions are proposed to eliminate them to improve the quality of the microassemblies, after which the value of the number of sigma has increased. Conclusions were made about the effectiveness of the use of the Six Sigma Methodology to reduce the release of defective products.

Keywords: Six sigma, quality, production process, defects, variability

1. Introduction
One of the most important indicators of the organization is the quality of products. Quality improvement determines the survival and competitiveness of an organization under market conditions, the rate of technical progress and the increase in production efficiency [1-4].

One of the methodologies for improving the work of an organization is the Six Sigma methodology. Six Sigma is a system of processes adjustments that aims to reduce all types of defects through consistent execution stages [5]. These stages are carried out to address the root causes of defects through quantitative studies of production processes [6-8]. The basic idea of management based on Six Sigma is that if it is possible to measure the number of defects in the process, then it is possible to determine how to eliminate them.

2. Quality assessment of microassemblies

2.1. Description of microassembly type 5UV4
This methodology was considered on the example of the production process of microassemblies 5UV4 at JSC «Mari Machine-Building Plant». A schematic diagram of the microassembly 5UV4 is presented in fig. 1.
The purpose of this type of microassemblies is a balanced amplifier. They are designed to amplify weak electrical signals in order to improve their noise immunity [9-12]. The main characteristics of microassemblies 5UV4 are presented in table 1.

### Table 1. Main technical characteristics of microassembly 5UV4 at a temperature of 25 ± 10 °C

| Characteristic                                      | Value               |
|-----------------------------------------------------|---------------------|
| Supply voltage, V                                  | 6,3±10%             |
| Steepness of the current-voltage characteristics, mA / v, not less | 5                   |
| Input resistance, Ohm, not less                     | 400                 |
| Output resistance, Ohm, not less                    | 50000               |
| Voltage gain                                        | 7,5 – 11,5          |

### 2.2. Determining the number of Sigma

The determining factor that characterizes the quality of microassemblies 5UV4 is the voltage gain µ. The change in this indicator of quality within 2 months is presented in table 2. A total of 1,440 microassemblies were produced. An average voltage gain was calculated for every 36 batches of 40 microassemblies.

### Table 2. The average value of the voltage gain

| Number series | 1    | 2    | 3    | 4    | 5    | 6    |
|---------------|------|------|------|------|------|------|
| µ             | 9,76 | 9,57 | 10,26| 11,27| 9,73 | 11,43|
| µ             | 7    | 8    | 9    | 10   | 11   | 12   |
| µ             | 7,45 | 8,75 | 8,58 | 8,16 | 8,36 | 8,87 |
| µ             | 13   | 14   | 15   | 16   | 17   | 18   |
| µ             | 8,37 | 7,54 | 9,47 | 11,43| 8,58 | 11,43|
| µ             | 19   | 20   | 21   | 22   | 23   | 24   |
| µ             | 10,32| 11,75| 9,73 | 8,37 | 9,98 | 7,54 |
| µ             | 25   | 26   | 27   | 28   | 29   | 30   |
| µ             | 9,73 | 8,31 | 8,87 | 9,68 | 10,26| 9,56 |
| µ             | 31   | 32   | 33   | 34   | 35   | 36   |
| µ             | 11,76| 8,16 | 8,81 | 9,57 | 9,68 | 10,4 |

A histogram of the distribution of the average values of the voltage gain was constructed using the STATISTICA program presented in fig. 2.
There is no stock of quality in this process because the width of the normal distribution curve is greater than the width of the tolerance range. This is the reason for the production of defective products.

\[ Y_{DPMO} = \frac{1000000 \cdot 26}{1440} = 18056 \]  \hspace{1cm} (1)

The number of sigma according to table A.1 - The number of sigma ISO 13053-1-2015 is equal to 3,5σ.

2.3. Assessment of the potential ability of the process to meet product quality requirements

A control chart of individual values of the voltage gain was built for clarity of the progress of the production process of microassemblies of type 5VB4 presented in fig. 3.
All values of the voltage gain are within the control limits. But there is a series of 8 points. This indicates that the production process of microassemblies of type 5UV4 is uncontrollable.

Then a quantitative assessment of the variability of the process in relation to the technical requirements was made. The value of the intrinsic variability of the process of production of microassemblies was calculated by the equation (2):

$$\hat{\sigma}_I = \frac{\bar{R}}{d_2} = \frac{3.58}{5.737} = 0.624,$$

(2)

$\bar{R}$ – average value of the ranges of individual samples;

$d_2$ – coefficient whose value depends on the size of individual samples.

The process reproducibility index is calculated by the equation (3):

$$C_p = \frac{USL - LSL}{6 \cdot \hat{\sigma}_I} = \frac{\Delta}{6 \cdot \hat{\sigma}_I} = \frac{4}{6 \cdot 0.624} = 1.068$$

$$USL$$ – upper tolerance limit;

$$LSL$$ – lower tolerance limit;

$$\Delta$$ – value of the tolerance zone.

The process is statistically stable, but uncontrollable, despite the fact that all values lie within the established boundaries since $1 < C_p < 1.33$. The width of the process is quite large compared with the specified requirements and the process does not correspond to them. This suggests the need to focus on improving the process aimed at reducing the variation in the quality of products.

3. Improving the quality of microassemblies

3.1. Identification of root causes of defective microassemblies

The change in the main indicator of quality of microassemblies 5UV4 caused by a number of inconsistencies, which are presented in table 3.

| The types of inconsistencies | Number |
|-----------------------------|--------|
| Cracks                      | 10     |
| Grease stains               | 21     |
| Chips                       | 1      |
| Solder beads                | 59     |
| Breaks of bridge            | 2      |
| Excess glue on the board    | 105    |
| Total                       | 198    |

Pareto chart of the inconsistencies of the microassembly 5UV4 was constructed using the STATISTICA program. It is presented in fig. 4. This diagram is used to identify the most significant factors affecting the occurrence of inconsistencies. Pareto chart gives you the opportunity to allocate efforts to resolve the problem.
The ABC analysis is based on the Pareto principle (also called the 80/20 rule), which states that about 80% of the effects come from about 20% of the causes. All inconsistencies were divided by the specific weight of each group with the help of ABC analysis.

Thus, if you eliminate such defects as excess glue on the board the effect will be 53.02% (group A), solder beads – 29.8% (group B), the remaining inconsistencies – 17.18% (group C).

### 3.2. Activities to improve the quality of microassemblies

The problem of defective microassemblies due to the instability and uncontrollability of the process was submitted on the production meeting «Quality Hour». The main reasons for the inconsistencies in the production process and the voltage gain variability were identified as a result of brainstorming. They are presented in the cause and effect diagram in fig. 5.

**Figure 4.** Pareto chart for the types of inconsistencies microbuses 5UV4

**Figure 5.** The cause and effect diagram of inconsistencies of microassemblies type 5YB4
Then a number of proposals to improve the production of micro-assemblies were received:
1. Apply the glue in two approaches with successive drying of each layer in air. The heating rate of the microassembly should be reduced to the flux activation temperature in order to avoid the formation of solder beads.
2. The introduction of control with a magnification of not less than 2.5X.
3. Introduction of technology of cleaning of a substrate on the set of equipment chemical cleaning
4. Carrying out unscheduled periodic certification of personnel.
5. Increasing requirements quality of resistors, capacitors and transistors.
6. Keeping a register of proposals for improving production with the aim of involving personnel in the system of collecting useful offers.

4. Quality assessment of microassemblies after the microassembly quality improvement activities

4.1. Determining the number of Sigma

The data of the voltage gain were re-collected after the implementation of the listed corrective actions. An average voltage gain was calculated for every 36 batches of 40 microassemblies. The results of the calculations are presented in table 4.

| Number series | 1  | 2  | 3  | 4  | 5  | 6  |
|---------------|----|----|----|----|----|----|
| \(\bar{\mu}\)  | 8.51 | 9.33 | 10.43 | 9.63 | 10.31 | 10.11 |
| Number series | 7  | 8  | 9  | 10 | 11 | 12 |
| \(\bar{\mu}\)  | 10.78 | 9.84 | 8.21 | 9.22 | 9.12 | 10.84 |
| Number series | 13 | 14 | 15 | 16 | 17 | 18 |
| \(\bar{\mu}\)  | 9.21 | 8.29 | 10.52 | 10.19 | 9.37 | 9.86 |
| Number series | 19 | 20 | 21 | 22 | 23 | 24 |
| \(\bar{\mu}\)  | 10.72 | 8.69 | 9.23 | 8.68 | 9.74 | 10.33 |
| Number series | 25 | 26 | 27 | 28 | 29 | 30 |
| \(\bar{\mu}\)  | 9.62 | 8.53 | 8.98 | 9.63 | 9.31 | 8.48 |
| Number series | 31 | 32 | 33 | 34 | 35 | 36 |
| \(\bar{\mu}\)  | 10.34 | 9.84 | 8.72 | 9.85 | 10.14 | 9.67 |

A histogram of the distribution of the average values of the voltage gain was constructed using the STATISTICA program presented in fig. 6. The frequency of the average value of the voltage gain in a given interval is located on the ordinate axis, and the value of the voltage gain is located on the abscissa axis.
There is a stock of quality in this process according to fig. 6. The width of the normal distribution curve has become smaller in width compared to the first histogram that was built before the corrective actions were applied.

The number of microassemblies not accepted from the first presentation is 26. Then the number of defects per million possible defects is calculated by the equation (4):

$$ Y_{DPMO} = \frac{1000000 \times 2}{1440} = 1389 \text{ pcs} $$

The number of sigma according to table A.1 - The number of sigma ISO 13053-1-2015 is equal to 4.4σ.

4.2. Assessment of the potential ability of the process to meet product quality requirements

A control chart of individual values of the voltage gain was built for clarity of the progress of the production process of microassemblies of type 5UV4 presented in fig. 7.
All values of the voltage gain are within the control limits. There are no trends and long series of points.

The value of the intrinsic variability of the process of production of microassemblies after carrying out corrective actions is calculated by the equation (5):

\[ \hat{\sigma}_I = \frac{\overline{R}}{d_2} = \frac{2.63}{5.412} = 0.486, \]

The process reproducibility index is calculated by the equation (6):

\[ C_p = \frac{USL - LSL}{6 \cdot \hat{\sigma}_I} = \frac{\Delta}{6 \cdot \hat{\sigma}_I} = \frac{4}{6 \cdot 0.486} = 1.372 \]

The process can be statistically stable and manageable since \( C_p > 1.33 \). The process is able to maintain the output characteristic of the production process at the level of established requirements.

5. Conclusion

Inconsistencies data that cause changes in the voltage gain values were collected.

### Table 5. The types and number of inconsistencies of microassemblies 5UV4

| The types of inconsistencies | Number |
|-----------------------------|--------|
| Cracks                      | 5      |
| Grease stains               | 16     |
| Chips                       | 0      |
| Solder beads                | 48     |
| Breaks of bridge            | 2      |
| Excess glue on the board    | 84     |
| Total                       | 155    |

The number of discrepancies decreased from 198 to 155, i.e. by 1.28 times. Due to this, the degree of variability of the voltage gain has decreased.

Thus, it is necessary to improve the production process to improve its quality. Product quality can be assessed by the position on the Six Sigma scale.

The Six Sigma methodology is applicable to all organizations regardless of their size and type of activity. Also this methodology can be implemented using various methods and tools of quality management, which should be selected based on the industry characteristics of the organization.

6. References

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