Analysis of Costs at the Production of Finishing Works with Guaranteed Quality Level

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Abstract. The aim of the work is to analyze the cost of finishing works. Object of research is paint application process on building products and design. Information is provided on the results of the cost analysis in the process of painting the surface of building products and structures, depending on the level of defectiveness at each stage of the process. Recommendations are given to improve the efficiency of the painting process, the application of statistical methods for managing product quality to the analysis of the process for obtaining paint coatings with specified properties. Determined, that in terms of the number of standard deviations and the level of defectiveness, the greatest attention is required by the surface cleaning operation, the priming of the cleaned surface and hardening of weak bases, as well as application of putty on the surface. Thus, consideration of economic costs on each stage of the process will allow the enterprise to find reserves for increasing production efficiency. The real way to reduce financial losses is to increase the number of standard deviations of quality indicators in the tolerance field, which is recommended by the six sigma methodology. To successfully reduce the cost of correcting defects, it is necessary methodology "six sigma", statistical methods of control and quality management of products, carry out preventive and corrective actions, as well as to evaluate failures leading to a decrease in profits, regardless of the reasons for their being caused.

1. Introduction

Any indicator characterizing the quality of products, as a rule, has one-sided and two-sided tolerances with specified values (UCL and LCL - upper and lower tolerance limits). Going beyond the tolerance limits leads to marriage. The more standard deviation σ of the process fits in the tolerance field, the fewer defects will be produced in production [1]. Table 1 shows the values of the probability of the output of a random variable on the tolerance limits for different values of root-mean-square deviations in the tolerance zone.

An excellent indicator is the hit (3-4) σ in the interval between the mean value and the control limit. This means the presence of 6200 defects per million products. The term "Six Sigma" arises when trying to achieve such a process variability that ± 6σ (the standard deviation estimate) is between the upper and lower tolerance limits for the process [2,3].

Consider the application of the six sigma methodology as applied to the production process. The level of defectiveness can be determined in accordance with the formula

\[ 1 - \frac{\text{number of defective units}}{\text{total number of products}} \]  

(1)
Table 1. Probability of output of a random value over the limits of tolerance \((m \pm k\sigma)\)

| \(\varepsilon / P\) | An arbitrary distribution law | Normal distribution law |
|---------------------|-------------------------------|-------------------------|
|                     | Two tail position             | One tail position       |
| \(2\sigma\)        | 25 000.10^4 \(10^{-6}\)     | 45 550.10^6 \(10^{-6}\) | 22 750.10^6 \(10^{-6}\) |
| \(3\sigma\)        | 111 100.10^6 \(10^{-6}\)    | 2 699.10^6 \(10^{-6}\)  | 1 395.10^6 \(10^{-6}\)  |
| \(4\sigma\)        | 32 500.10^6 \(10^{-6}\)     | 63 372.10^6 \(10^{-6}\) | 31 686.10^6 \(10^{-6}\) |
| \(5\sigma\)        | 40 000.10^6 \(10^{-6}\)     | 0.5742.10^6 \(10^{-6}\) | 0.2875.10^6 \(10^{-6}\) |
| \(6\sigma\)        | 27 700.10^6 \(10^{-6}\)     | 0.00198.10^6 \(10^{-6}\) | 0.001.10^6 \(10^{-6}\)  |

Figure 1 shows the "ideal" process (curve 1), when the mean and standard deviation (SD) of quality indicators provide an ideal quality, and the "critical" process (curve 2), in which even the slightest deterioration in parameters or an increase in the SD will lead to an excess of the permissible defect rate [4].

Suppose that the process deviated from the average by 1.5\(\sigma\) and that the number of products is 100,000. Then the number of products whose quality indicators will be below the lower control limit will be 66.807. Thus, it is necessary to strive for such a variance for the process, so that \(\pm 6\sigma\) fits within the interval from the lower control limit to the mean. In this case, even the displacement of the process will not lead to the appearance of a large number of defects. In this case, even if the process average shifts by 1.5\(\sigma\) (for example, by +1.5 sigma closer to the upper boundary), the number of defects remains very small and amounts to only 3.4 defects per million possibilities [5,6,7].

2. The results of research

When we evaluate the quality of the final product, the low value of the defectiveness level at first glance indicates the efficiency of the production process. However, if we consider the internal indicators of defectiveness, they allow us to present in quantitative terms the amount of improvements during the process. Consider the analysis of the defectiveness of the process on the example of obtaining protective and decorative coatings for building products and structures [8,9,10].
accordance with TR 140-03 "Technical recommendations on the technology of painting interiors and facades of residential and public buildings under construction", the process of painting involves the following operations:

- surface cleaning;
- priming of the cleaned surface and hardening of weak crumbling bases;
- application of putty;
- padding;
- painting of the first layer of paint;
- painting a second coat of paint.

Suppose that the data at the output of the process indicate that the final output of high-quality colored products is 98%, i.e. of the 1000 painted products 980 products are painted without marriage, and 20 products are rejected (defectiveness level value is 2%).

As already noted, the process of painting works consists of 6 operations, each of which works with a certain level of defectiveness. Suppose that in the process of operational control, defective products were identified, which were sent for revision. In Table 1 the values of the quality level at each stage of the process are given.

Analysis of the data (Table 2) shows, that the number of units sent for revision is 84. The actual quality of the process is:

\[
1 - \frac{84 \text{ work. units}}{1000} = 0.916 = 91.6\%
\]

Therefore, the quality level value of 98% does not reflect the real picture of the quality of the process.

| №  | Name operations                              | Number of units at the entrance | Number of units at the exit | Number of units for revision | Process quality, % |
|----|---------------------------------------------|---------------------------------|----------------------------|----------------------------|-------------------|
| 1  | Surface cleaning                            | 1000                            | 970                        | 30                         | 97.0              |
| 2  | Priming of a cleaned surface and hardening of weak crumbling bases | 970                            | 950                        | 20                         | 97.93             |
| 3  | Application of putty                         | 950                            | 935                        | 15                         | 98.42             |
| 4  | Padding                                     | 935                            | 930                        | 5                          | 99.46             |
| 5  | Painting of the first coat of paint          | 930                            | 926                        | 4                          | 99.57             |
| 6  | Painting of the second coat of paint         | 926                            | 916                        | 10                         | 98.92             |

This discrepancy between the quality indicators of 98% and 91.6% is due to the fact that the figure of 98% "hides" the defects that are eliminated during the process. 84 units were sent for revision, 64 of them were corrected and returned to the staining process.

Based on the normal distribution law, the standard deviation of the quality index is equal to:

- the first option (calculation based on the final result) - 2.33 $\sigma$
- the second option (considering the level of defectiveness at each stage of the process) -1.73 $\sigma$
For each operation of the staining process, it is calculated how many standard deviation values are in the tolerance field (Table 3).

**Table 3. Standard deviation values in the tolerance field**

| No. | Name operations                                      | Number of standard deviations $\sigma$ |
|-----|-----------------------------------------------------|---------------------------------------|
| 1   | Surface cleaning                                     | 2.17 $\sigma$                         |
| 2   | Priming of a cleaned surface and hardening of weak crumbling bases | 2.3 $\sigma$                         |
| 3   | Application of putty                                 | 2.42 $\sigma$                         |
| 4   | Padding                                              | 2.78 $\sigma$                         |
| 5   | Painting of the first coat of paint                  | 2.86 $\sigma$                         |
| 6   | Painting of the second coat of paint                 | 2.54 $\sigma$                         |

The analysis of the data (Tables 2 and 3) shows, that in terms of the number of standard deviations and the level of defectiveness, the greatest attention is required by the surface cleaning operation, the priming of the cleaned surface and hardening of weak bases, as well at application of putty on the surface.

Suppose that products have dimensions of 1.5 x 6 m. In accordance with TEP 81-02-15-2001 in the Penza region, the damage caused by the fact that 20 products (with an area of 180 m²) were found to be defective:

$$Y = 3 \cdot K_{index} \cdot S = 1830.48 \cdot 4.491 \cdot 1.8 = 14797.24 \text{ Rub.}$$

where

- $Y$ - damage (less profit), Rub;
- $K_{index}$ - indexation coefficient, which is 4.491 (with VAT and materials);
- $S$ - direct costs, including payment for labor, materials, operation of machines;
- $S$ - increase in area compared to 100m².

Suppose, that defects were committed:

- when application of putty on surface (15 units were sent for revision);
- when cleaning the surface, priming a cleaned surface and hardening of weak crumbling bases (20 units were sent for revision).

In addition direct costs are:

- when application of putty on surface (the area of 15 products is 135 m²);
- when cleaning the surface, priming the cleaned surface and hardening the weak crumbling grounds 20 products with an area of 180 m².

$$\Delta S = 3 \cdot K_{index} \cdot S = 3600 \text{ Rub}.$$  \hspace{1cm} (4)

Thus, additional direct costs are

$$\Delta S = 2264.9 + 3600 + 14797.24 = 20669.14 \text{ Rub.}$$  \hspace{1cm} (5)
3. Conclusions
Thus, consideration of economic costs at each stage of the process will allow the enterprise to find reserves for increasing production efficiency. The real way to reduce financial losses is to increase the number of standard deviations of quality indicators in the tolerance field, which is recommended by the six sigma methodology. To successfully reduce the cost of correcting defects, it is necessary to carry out preventive and corrective actions, as well as to evaluate failures leading to a decrease in profits, regardless of the reasons for their being caused.

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