Experimental research based on statistical control, aimed to improve the quality of the parts obtained through machining, at some consumer goods

L Dragan
Technical University of Cluj-Napoca, Faculty of Engineering, Department of Engineering and Technology Management, Baia Mare, Romania

E-mail: liliana.dragan@cunbm.utcluj.ro

Abstract. The paper aims to carry out experimental research meant to increase the quality of some mass-produced furniture items. In order for that to happen, a great number of size measurements have been done on beech and birch wood parts obtained through milling and drilling with numerically controlled machines. The experiment lasted for a week, with work being done in two shifts and with a volume of 300 parts per shift. The experimental database was then processed and interpreted in line with the statistical analysis methods. Finally, conclusions regarding the measures that need to be taken in order to assure an accurate adjustment of the machine as well and an optimisation of the production process were formulated.

1. Introduction
The quality of an industrial product must satisfy the customer’s needs. These must be specified, controlled and observed during the manufacturing process. In this context quality is a complex concept that includes issues related to conception, manufacturing and use.

To solve this problem, we rely on statistical control. This is a modern mean to monitor the manufacturing process and to assess the quality, the manufactured parts having to fulfil a number of conditions: to be manufactured in large scale; to have a significant share in the company’s production; to be manufactured using an automatic or semi-automatic technological process.

Attention is directed to three levels of statistical control [1]:
- Quality planning (planning level) setting the preliminary parameters: monitored features, the number of units contained in the survey sample, type of control card, evaluation;
- Quality verification (operational level): determining the measured values, documentation on verification data, documentation of the process development, process control based on control cards;
- Quality adjustment (administrative level): long-term forecasts are issued based on verification reports and the process is optimized.

2. Data on the manufacturing process
The paper aims to analyse the stability of the process of drilling parts (figure 1) used to make sofas, in a wooden plate cutting workshop. The process is done on multiple drilling machines (figure 2) which
are simultaneously using 6 drills, whose adjustment is essential. This study is required following the observation that some components of the sofa’s structure show a higher percentage of rejects.

![Figure 1. The monitored part](image1)

![Figure 2. The multiple drilling machine used for processing](image2)

Manufacturing process control [2] is done by sampling, through surveys and calculations based on probability theory and mathematical statistics. In this regard, a preliminary statistical analysis was done, setting the dispersion parameters (mean square deviation $\sigma$), then the quality control cards were issued, meant to monitor the capacity of the process to be kept under control.

3. Data on statistical control

Manufacturing quality can be estimated/assessed by the measurement of some discrete variable features of the product in accordance with the requirements of the technical documentation. For the samples taken successively, for values of the features in the survey sample, two parameters were monitored, one related to the machine adjustment - by the position of the field scattering (median), and the other one concerning the accuracy of processing - by the size of the field dispersion (amplitude). Depending on their position against the limits calculated and plotted for each one, given a significance level $\alpha = 0.002$, the manufacturing process is assessed and measures to correct possible occurrences are provided: optimum / excessive / insufficient precision and centered/decentered process. Each time it is assessed if there are prerequisites for worsening the current situation over time and whether stoppage and correction of the process is economically justified.

The size of the survey sample is $n = 5$ units. The sample consists of the last pieces taken from the machine in their production order, complying with the recommendation that the proportion of controlled parts represent 5÷10% of the batch if normal series. The proportion of controlled pieces can be estimated using the formula [3]:

$$\text{Proportion} = \frac{\text{Number of controlled parts}}{\text{Total number of parts}}$$
n is the size of the survey sample; 
Q is the average number of pieces drilled between two successive samplings or dis-adjustments (600); 
\( \Delta t \), the time interval between two samplings, determined by the formula:

\[
\Delta t = \frac{60}{q} \cdot \sqrt{n \cdot Q} = \frac{60}{70} \cdot \sqrt{5 \cdot 600} \approx 1 \text{ or a} 
\]

q is the hourly production of the machine (70/h).

4. Processing the results of measurements. Preliminary statistical analysis

Considering the standard tolerances specified for the monitored size, the distance between the hole and the edge of the part was measured using a calliper with 0.01 mm precision.

After the collection of the measured results over several 8 hour shifts, the data was analysed and one important dimension of the product were determined: 185 ± 0.5 mm. For this size, the sequence of measured values was divided into 10 groups, for each group the followings were set: absolute frequencies, relative frequencies, the distribution function, and finally, the mean square deviation and data dispersion for the measured values (figure 3). The data of the preliminary analysis were entered in Excel program [4] and were the basis for drawing the histogram (figure 4), the frequency polygon and the graph of the distribution function (figure 5).

![Figure 3. Summarization of data from the preliminary analysis](image)

![Figure 4. The histogram](image)
5. Drawing up the control cards

The classic control cards allow continuous monitoring of the process, enabling a constant and predictable production both in terms of cost and quality. There is also a reduction of products dispersion, a cost reduction and an increase in the effective capacity of the process to be kept under control. To allow the identification of the causes of errors, all the changes and influences on production must be mentioned in the sheet accompanying the process [5].

The control cards [2] contain the following: general information (department, machine, product, operation, monitored feature, limits of the tolerance interval, size of the sample, the interval between two samplings); date and time of sampling; diagrams of the monitored parameters; the measured values and the accuracy of the measuring instrument used; the values of the parameters (average / standard deviation, median / amplitude); conclusion of the survey and decision.

The diagrams of the location parameter (average / median) contain the control limits (upper Lcs and lower Lci) and tolerance limits (upper Ls and lower Li), while the diagrams of the variation parameter (standard deviation / amplitude) need only the upper control limit.

If a location parameter (median ME) with bilateral risk is monitored, the values of the control limits are calculated as follows:

$$L_{CS} = T_c + 1,2533 \cdot z_{\alpha} \cdot \frac{\sigma}{\sqrt{n}}$$  \hspace{1cm} (3)

$$L_{CI} = T_c - 1,2533 \cdot z_{\alpha} \cdot \frac{\sigma}{\sqrt{n}}$$  \hspace{1cm} (4)

$$ME = \frac{x_{n+1}}{2}$$  \hspace{1cm} (5)

$T_c$ - middle of the tolerance interval.

If a variation parameter like amplitude $R$ is monitored, it requires a single control limit $L_c$. Because only positive deviations are of interest, the unilateral risk is adopted.

$$L_c = \frac{t_{\alpha} \cdot \sigma}{2}$$  \hspace{1cm} (6)

$$R = x_{max} - x_{min}$$  \hspace{1cm} (7)

$x_{max}$ and $x_{min}$ are the limit values of the feature.
It was noted that the frequency distribution has a single maximum, meaning that the measured values observed the normal distribution. The preliminary analysis is used to set the mean square deviation and then the control cards for median and amplitude are drawn up (figure 6 and figure 7).

Only two control cards are presented here, covering four consecutive shifts, in which the most significant developments of the monitored statistical parameters were observed.

**Figure 6.** The control card for median and amplitude, drawn up for 31.10.17

**Figure 7.** The control card for median and amplitude, drawn up for 1.11.17
6. Conclusion
The analysis of the drilling process during 16 shifts revealed the following:
For dimension $\phi\ 10.5 \pm 0.2$ mm:
- for the survey samples of 30 October / shift 1 the successive parameters of the median are on the same side of the mean value, towards the upper values, and they are located outside the control and tolerance limits; also for shift 2 there are parameters outside the control limits;
- for the survey samples of 1 November / shift 1 there are successive parameters of the median on the same side of the mean value, but within the control limits, and for shift 2 there are also parameters outside the control limits.

For dimension $185 \pm 0.5$ mm:
- On 30 October / shift 1 the median parameters are also on the same side of the mean value, towards the upper values, and they are also located outside the control and tolerance limits; for shift 2 the median parameters were located within the control limits;
- For samples of 1 November / shift 1 and 2 the median parameters fall on both sides of the mean value, within the control limits.

In all analysed cases the amplitude parameters were located within the control limits.

It could be concluded that on 30 October the adjustment of the machine was faulty, and then the process parameters were reset so that on 1 November the results were acceptable. However, the fact that on 1 November / shift 1, more than 2/3 of the parameters were situated in the middle third of the interval may raise a suspicion that the recorded data were “doctored”.

Nevertheless, an amplitude jump should be noted at the beginning of shift 2, which may be associated with changing the operator on the machine. The explanation could be frequent machine adjustments, which would result in lower productivity.

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