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STATISTICAL ANALYSIS BASED ON CONTROL CARDS AIMED TO IMPROVE THE QUALITY OF SOME MASS FURNITURE PARTS

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Abstract: *The quality of an industrial product is a complex concept that includes issues related to conception, manufacturing process and use. To improve the quality of the wood parts obtained through CNC machining, a great number of measurements have been done as part of a statistical control. A series of dimensions obtained through milling and drilling were analysed. The experiment lasted for several weeks, in two shifts. The experimental database was processed with the help of cards control, which monitored two statistical parameters such as median and amplitude. Based on these facts, a few conclusions have been drawn.*

Key words: *Statistical control of a manufacturing process by measurement, control cards*

1. INTRODUCTION

The paper aims to carry out experimental research meant to increase the quality of some mass produced furniture items [1][2][9]. 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 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 optimization of the production process were formulated.

The quality of an industrial product must satisfy the customer's needs. These must be specified, controlled and observed during the manufacturing process.

To solve this problem we rely on statistical control [3]. 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.

2. DATA ON THE MANUFACTURING PROCESS

The paper aims to analyze the stability of the process of drilling parts (Fig. 1) used to make sofas, in a wooden plate cutting workshop. The process is done on multiple drilling machines (Fig. 2) which are simultaneously using 6 drills [4], 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.

Manufacturing process control [5] 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 σ), then the quality control cards were issued, meant to monitor the capacity of the process to be kept under control.

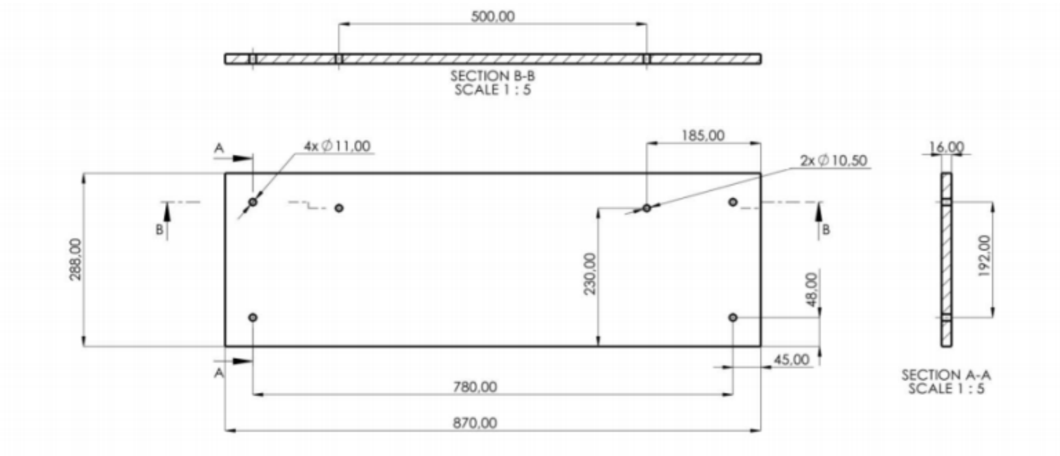

Fig. 1. The monitored part

Fig. 2. The multiple drilling machine used for processing

3. DATA ON THE STATISTICAL ANALYSIS

Manufacturing quality can be estimated 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 α = 0.002, the manufacturing process is assessed and measures to correct possible occurrences are provided: optimum / excessive / insufficient precision and centred / decentred process [5]. 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][6]:

$$k = 100 \cdot \sqrt{\frac{n}{Q}} = 100 \cdot \sqrt{\frac{5}{600}} \cong 9\% \qquad (1)$$

n is the size of the survey sample;

Q is the average number of pieces drilled between two successive samplings or disadjustments (600),

Δt, the time interval between two samplings, determined by the formula:

$$\Delta t = \frac{60}{q} \cdot \sqrt{n \cdot Q} = \frac{60}{70} \cdot \sqrt{5 \cdot 600} \sim 1\, ora \qquad (2)$$

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

4. PROCESSING THE RESULTS OF MEASUREMENTS. PRELIMINARY STATISTICAL ANALYSIS

The results will be presented as a report that includes: presentation of the primary data; tabular representation of the calculated values of monitored features in the control cards;
representation of the limits of control intervals for the monitored parameters; representation of data required for process verification; presentation of the assessment criteria and recommended behaviour.

Following the discussion with the production workers it was determined that the monitored dimensions were ϕ10,5±0,2mm, ϕ11±0,3mm, 45±0,5mm, 185±0,5mm. 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 (Table 1).

Results of preliminary statistical analysis ***Table 1***

	MIN	MAX	Media	Mediana	Modulul	Abaterea standard	Dispersia	Amplitudinea
Dist. gaura 11 pe axa X (45)	43,38	46,03	44,8782	44,91	45,11	0,352453336	0,124223354	1,43
Dist. gaura 10,5 pe axa X (185)	184,5	185,5	184,98896	184,96	185,06	0,265365504	0,070418851	2,14
Diametru 11	9,7	11,13	10,67067	10,68	0,200204	0,200204419	0,040081809	1,43
Diametru 10.5	10,3	10,7	10,720893	10,715	10,87	0,181532781	0,032954151	0,89

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

After the collection of the measured results, (Fig. 3 and Fig. 4, for three days) over several 8 hour shifts, the data was analysed.

Fig. 3. Results obtained by hourly measurements, on 31 Oct

Fig. 4. The measured results on 1and 2 Nov

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 (Table 2, Table 3).

The data of the preliminary analysis were entered in Excel program [6][7] and were the basis for drawing the histograms, the frequency polygons and the graphs of the distribution function, for each of the four dimensions (for example for size 45 mm as in Fig. 5 and Fig. 6).

Summarization of data from the preliminary analysis, for size 185 mm

Table 2

Nr clasei	Limitele claselor		Frecventa absoluta, n_i	Frecventa relativa, $f_i = \frac{n_i}{n}$	F(x)	x_i	$f_i * x_i$	σ	σ^2
1	184,00	184,216	14	0,029166667	0,029167	184,108	5,3698167	0,265365504	0,0704189
2	184,217	184,433	23	0,047916667	0,077083	184,325	8,8322396		
3	184,434	184,65	45	0,09375	0,170833	184,542	17,300813		
4	184,651	184,67	7	0,014583333	0,185417	184,6605	2,6929656		
5	184,868	185,084	237	0,49375	0,679167	184,976	91,3319		
6	185,085	185,301	63	0,13125	0,810417	185,193	24,306581		
7	185,302	185,518	45	0,09375	0,904167	185,41	17,382188		
8	185,519	185,735	8	0,016666667	0,920833	185,627	3,0937833		
9	185,736	185,952	24	0,05	0,970833	185,844	9,2922		
10	185,953	186,17	14	0,029166667	1	186,0615	5,4267938		
							185,02928		

Summarization of data from the preliminary analysis, for size ϕ10,5 mm

Table3

Nr clasei	Limitele claselor		Frecventa absoluta, n_i	Frecventa relativa, $f_i = \frac{n_i}{n}$	F(x)	x_i	$f_i * x_i$	σ	σ^2
1	9,700	9,842	1	0,0020833333	0,0020833333	9,771	0,0203563	0,20020442	0,040081809
2	9,843	9,985	1	0,0020833333	0,0041666667	9,914	0,0206542		
3	9,986	10,128	3	0,0062500000	0,0104166667	10,057	0,0628563		
4	10,129	10,271	9	0,0187500000	0,0291666667	10,2	0,19125		
5	10,272	10,414	32	0,0666666667	0,0958333333	10,343	0,6895333		
6	10,415	10,557	64	0,1333333333	0,2291666667	10,486	1,3981333		
7	10,558	10,700	152	0,3166666667	0,5458333333	10,629	3,36585		
8	10,701	10,843	119	0,2479166667	0,7937500000	10,772	2,6705583		
9	10,844	10,986	73	0,1520833333	0,9458333333	10,915	1,6599896		
10	10,987	11,130	26	0,0541666667	1	11,0585	0,5990021		
							10,678183		

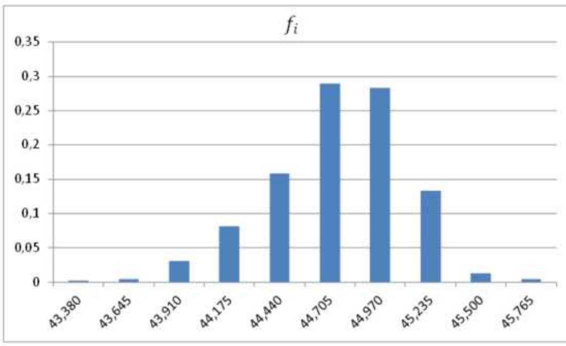

Fig. 5. The histogram, drawn for size 45 mm

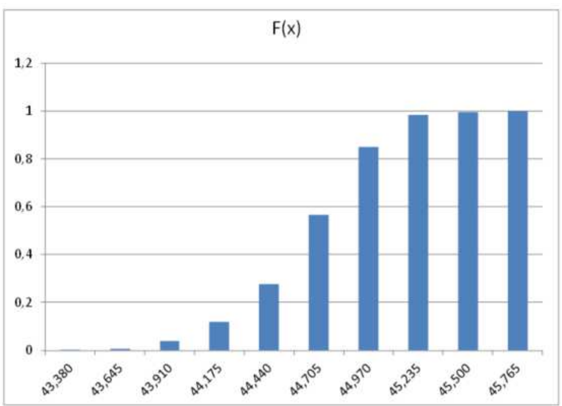

Fig. 6. The field dispersion, for size 45 mm

5. DRAWING UP THE CONTROL CARDS

The classic control cards [3] 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.

The control cards [5] 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:

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

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

$$ME = X_{\frac{n+1}{2}} \quad (5)$$

Tc - middle of the tolerance interval.

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

$$L_C = t_{\frac{\alpha}{2}} \cdot \sigma \tag{6}$$

$$R = x_{max} - x_{min} \tag{7}$$

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, for each working day and for each monitored size separately. A large number of control cards were generated, which were subsequently analysed.

Only two control cards are presented here (Fig.7 and Fig.8, for size 185 mm and for 31 Oct and 1 Nov), covering four consecutive shifts, in which the most significant developments of the monitored statistical parameters were observed.

Similarly, control cards were drawn up for hole diameter ϕ 10.5 ± 0.2 mm during the same shifts.

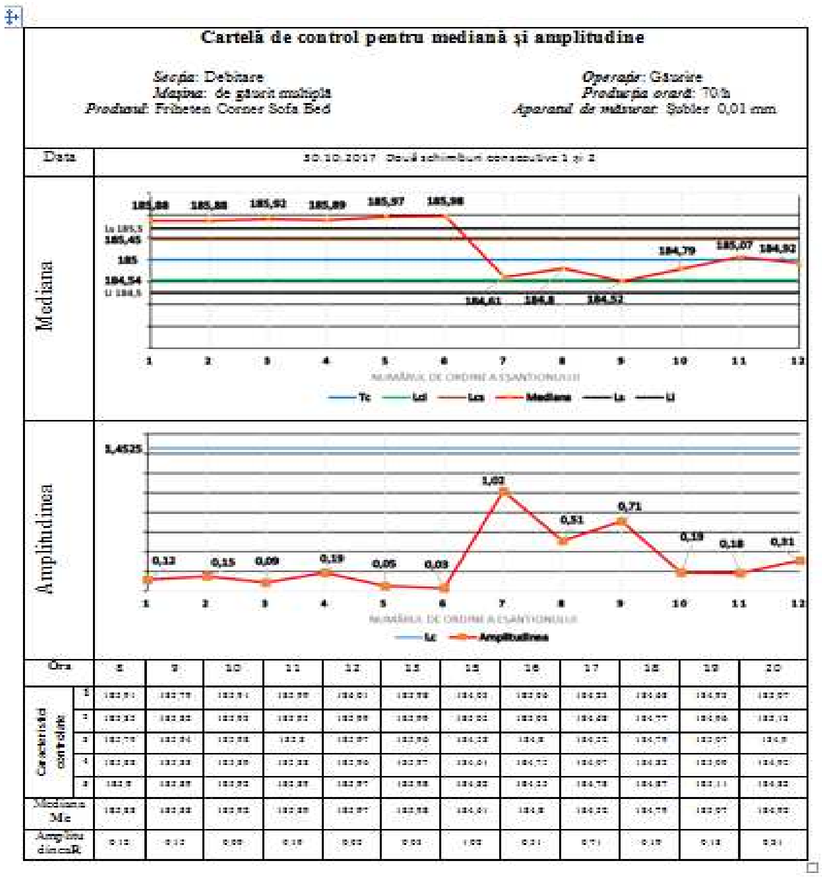

Fig. 7. The control card for median and amplitude drawn up for 31 Oct

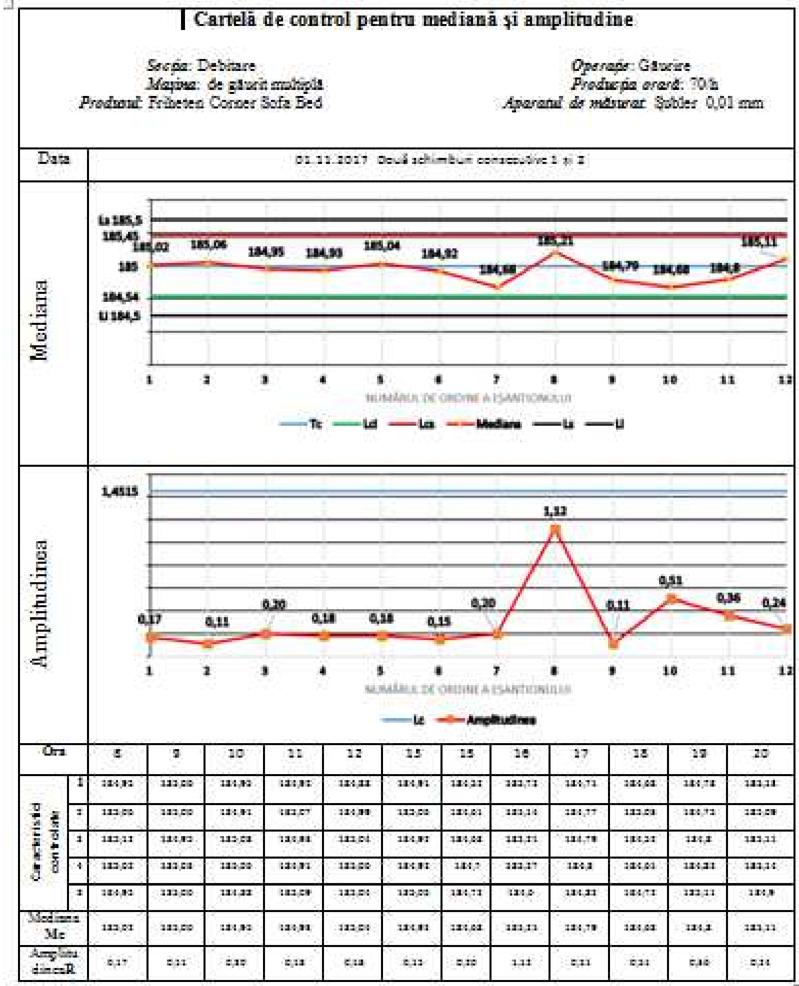

Fig. 8. The control card for median and amplitude drawn up for 1 Nov

6. CONCLUSION

The analysis of the drilling process- for the two dimensions pertaining to hole ϕ 10.5 mm and during the respective days/shifts - revealed the following.

For dimension 185 ± 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 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.

For diameter ϕ 10.5 ± 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.

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, 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.

In conclusion it is noted that the drilling accuracy was generally appropriate, instead problems occurred in the adjustment of the machine, which can be explained by the frequent changing of operators.

7. REFERENCES

[1] Pop, E., Steopan, M., Ciupan, C., Filip, I., *Decreasing the mass of a sofa side made of composite materials based on vegetable fibers*, Acta Technica Napocensis, Series: Applied Mathematics, Mechanics and Engineering, ISSN 2393-2988, vol.61, No.4, 2018

[2] Badiu, A., Badiu, I., Dragomir, M., *Studies regarding the use of reclaimed wood in the manufacture of modern furniture*, Acta Technica Napocensis, Series: Applied Mathematics, Mechanics and Engineering, ISSN 2393-2988, vol.58, No.2, 2015

[3] Tanasescu, I., *Controlul statistic al produselor si proceselor*, Ed. Didactică și Pedagogică, București, 1987

[4] Ivan M., Antonescu N., Dumitraș C., Rusan Gh., Bădescu Gh., Popescu I., 1980 *Mașini-unelte și control dimensional*, Ed. Didactică și Pedagogică, București, 1980

[5] Bulgaru M., Bolboacă L., *Ingineria calității. Managementul calității, statistică și control, măsurări în 3D*, Ed. Alma Mater, ISBN 973-85153-0-0, Cluj-Napoca, 2001

[6] Banica, M., Medan, N., *Statistical Analysis of the Experimental Data Obtained in Studying of Water Jet Cleaning*, Academic Journal of Manufacturing Engineering, Vol. 13, Issue 1/2015, pp.6-11, ISSN 1583-7904, 2015

[7] Cathy, K., *Excel pentru Windows,* Ed. Teora, ISBN 973-601-457-6, București, 1999

[8] Neamtu, C., Popescu, D., Mateescu, R., Hurgoiu, D., Pupeza, P., *Reconstution of ceramic vessels from the family of chiups*, Acta Technica Napocensis, Series: Applied Mathematics, Mechanics and Engineering, ISSN 2393-2988, vol.54, No.2, 2011

[9] Scurtu, L.I., Bodi, St., Dragomir, M., *Optimization methods applied in CAD based furniture design,* Acta Technica Napocensis, Series: Applied Mathematics, Mechanics and Engineering, ISSN 2393-2988, vol.58, No.4, 2015

Utilizarea cardurilor de control pentru imbunatatirea calitatii unor piese de mobilier

Rezumat. Lucrarea isi propune sa prezinte rezultatele experimentale obtinute prin masurarea catorva dimensiuni apartinand unei piese din lemn de fag prelucrate pe MUCN, pe durata mai multor saptamani de lucru in doua schimburi. Cu baza de date obtinute, s-a facut o analiza statistica preliminara si apoi s-au construit carduri de control pe baza de mediana si amplitudine, pentru fiecare din cotele analizate. S-au prezentat mai multe informatii in legatura cu dimensiunile considerate critice. S-a observat evolutia punctelor in raport cu limitele de control si limitele campurilor de toleranta. S-a concluzionat ca procesul de fabricatie monitorizat poate fi corectat prin realizarea mai eficienta a reglajului masinii si prin responsabilizarea mai atenta a operatorilor.

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