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The contribution of statistical processes in the control of technological processes

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Abstract. *In this paper, a manufacturing process is analyzed, having as quality characteristic the "height of the screw head", using analyzes and representative diagrams. Based on this case study, the way to solve these types of problems using the Quality Control Chart module of the WinQSB program, as well as the XLSTAT program is presented.*

Keywords*: WinQSB, XLSTAT, statistical control, control sheets, centering, accuracy*

1. Introduction

The manufacture of high quality products is of particular economic importance, "a first-class requirement of industrial enterprises" [7]. Products that have a higher quality are much more sought after by customers and purchased in a much larger volume, and the lack of this quality affects the entire organization.

Industrial enterprises use "two product quality control groups, namely:

a) deterministic control methods;

b) probabilistic or statistical control methods" [7].

"The main statistical procedures used in the study of processes are the so-called Process Control Chats, which although they have a long "historical career" – the first statistical control sheet being practically invented and applied in 1924 – did not "age" with the entry in the age of digitalization. On the contrary, the current possibilities of calculation allow, together with the use of modern means of measurement, to obtain larger data collections, and their statistical processing to take place almost instantly" [15].

2. Input data of the problem

The studied reference is represented by an M8 screw with a fully threaded hexagonal head, and the quality characteristic of interest is the height of the screw head (Characteristic 1) of size 5.2 ± 0.05 mm. In this sense, 4 samples of 5 measurements per day were taken from the production process, at an interval of 2 hours per shift, for a week.

Number	Date	Time	Subgroup	Characteristic 1
1	08.06.2020	10	1	5.17
2	08.06.2020	10	1	5.15
3	08.06.2020	10	1	5.16
4	08.06.2020	10	1	5.17
5	08.06.2020	10	1	5.15
6	08.06.2020	12	1	5.15
7	08.06.2020	12	1	5.17
8	08.06.2020	12	1	5.15
9	08.06.2020	12	1	5.16
10	08.06.2020	12	1	5.17
11	08.06.2020	14	1	5.17
12	08.06.2020	14	1	5.15
13	08.06.2020	14	1	5.17
14	08.06.2020	14	1	5.20
15	08.06.2020	14	1	5.22
16	08.06.2020	16	1	5.26
17	08.06.2020	16	1	5.25
18	08.06.2020	16	1	5.17
19	08.06.2020	16	1	5.26
20	08.06.2020	16	1	5.25
21	09.06.2020	10	2	5.15
22	09.06.2020	10	2	5.16
23	09.06.2020	10	2	5.18
24	09.06.2020	10	2	5.17
25	09.06.2020	10	2	5.19
26	09.06.2020	12	2	5.19
27	09.06.2020	12	2	5.17
28	09.06.2020	12	2	5.15

Number	Date	Time	Subgroup	Characteristic 1
29	09.06.2020	12	2	5.16
30	09.06.2020	12	2	5.14
31	09.06.2020	14	2	5.13
32	09.06.2020	14	2	5.19
33	09.06.2020	14	2	5.19
34	09.06.2020	14	2	5.26
35	09.06.2020	14	2	5.17
36	09.06.2020	16	2	5.17
37	09.06.2020	16	2	5.26
38	09.06.2020	16	2	5.25
39	09.06.2020	16	2	5.26
40	09.06.2020	16	2	5.25
41	10.06.2020	10	3	5.17
42	10.06.2020	10	3	5.15
43	10.06.2020	10	3	5.16
44	10.06.2020	10	3	5.15
45	10.06.2020	10	3	5.17
46	10.06.2020	12	3	5.19
47	10.06.2020	12	3	5.19
48	10.06.2020	12	3	5.17
49	10.06.2020	12	3	5.15
50	10.06.2020	12	3	5.16
51	10.06.2020	14	3	5.15
52	10.06.2020	14	3	5.16
53	10.06.2020	14	3	5.26
54	10.06.2020	14	3	5.19
55	10.06.2020	14	3	5.19
56	10.06.2020	16	3	5.16

Number	Date	Time	Subgroup	Characteristic 1
57	10.06.2020	16	3	5.26
58	10.06.2020	16	3	5.25
59	10.06.2020	16	3	5.20
60	10.06.2020	16	3	5.17
61	11.06.2020	10	4	5.15
62	11.06.2020	10	4	5.16
63	11.06.2020	10	4	5.17
64	11.06.2020	10	4	5.17
65	11.06.2020	10	4	5.24
66	11.06.2020	12	4	5.24
67	11.06.2020	12	4	5.26
68	11.06.2020	12	4	5.25
69	11.06.2020	12	4	5.15
70	11.06.2020	12	4	5.16
71	11.06.2020	14	4	5.14
72	11.06.2020	14	4	5.13
73	11.06.2020	14	4	5.17
74	11.06.2020	14	4	5.19
75	11.06.2020	14	4	5.19
76	11.06.2020	16	4	5.23
77	11.06.2020	16	4	5.26
78	11.06.2020	16	4	5.25
79	11.06.2020	16	4	5.14

Number	Date	Time	Subgroup	Characteristic 1
80	11.06.2020	16	4	5.13
81	12.06.2020	10	5	5.17
82	12.06.2020	10	5	5.22
83	12.06.2020	10	5	5.15
84	12.06.2020	10	5	5.16
85	12.06.2020	10	5	5.15
86	12.06.2020	12	5	5.22
87	12.06.2020	12	5	5.17
88	12.06.2020	12	5	5.17
89	12.06.2020	12	5	5,15
90	12.06.2020	12	5	5.19
91	12.06.2020	14	5	5.19
92	12.06.2020	14	5	5.15
93	12.06.2020	14	5	5.16
94	12.06.2020	14	5	5.22
95	12.06.2020	14	5	5.14
96	12.06.2020	16	5	5.13
97	12.06.2020	16	5	5.26
98	12.06.2020	16	5	5.25
99	12.06.2020	16	5	5.14
100	12.06.2020	16	5	5.13

Figure 1. The input data of the problem using the WinQSB program

The data collected (measured values for each product unit in the sample) are entered in the Quality Control Chart module of the WinQSB program, in fig. 1.

3. Analysis

We first perform a statistical analysis of the recorded data, by subgroups (days) and total [9]. So the statistical control is applied using the method of the arithmetic average and the amplitude of the scattering for each sample of size n = 5 pcs, and the obtained results are presented in fig. 2.

	23:03:22		Monday	July	19	2021			
Sample	Sample Size	Mean	Median	Midrange	Variance	S.D.	Range	Maximum	Minimum
1	20	5.1850	5.1700	5.2050	0.0016	0.0398	0.1100	5.2600	5.1500
2	20	5.1895	5.1750	5.1950	0.0018	0.0427	0.1300	5.2600	5.1300
3	20	5.1825	5.1700	5.2050	0.0013	0.0355	0.1100	5.2600	5.1500
4	20	5.1890	5.1700	5.1950	0.0022	0.0470	0.1300	5.2600	5.1300
5	20	5.1760	5.1650	5.1950	0.0015	0.0390	0.1300	5.2600	5.1300
Overall	20	5.1844	5.1700	5.1990	0.0017	0.0408	0.1220	5.2600	5.1300

Figure 2. Summary analysis

The arithmetic mean "represents the best estimator of the central position of the distribution of measured values" [18] and "measures the stability over time of the process adjustment, and the amplitude measures the stability of the accuracy over time of the manufacturing process" [14].

For each quality control problem the module predefines a set of 14 rules (fig. 3), which can be modified using the *Edit* menu options:

Number	Rule Description
1	Single Point Above UCL
2	Single Point Below LCL
3	2 of 3 Points Above 2 Sigma
4	2 of 3 Points Below 2 Sigma
5	4 of 5 Points Above 1 Sigma
6	4 of 5 Points Below 1 Sigma
7	8 Points in a Row Above CL
8	8 Points in a Row Below CL
9	8 Points in a Row Above Median
10	8 Points in a Row Below Median
11	8 Points in a Row Up
12	8 Points in a Row Down
13	Single Point Jumps Up 2 Sigma
14	Single Point Jumps Down 2 Sigma
15	Rule 15

Figure 3. The 14 rules offered by the WinQSB program

The analysis is continued with the "elaboration of representative diagrams, available in the Gallery menu, first of all the control sheets for data obtained" by measurement "which can be of several types:

- control sheets for averages/mean (X-bar (Mean) Chart – fig. 4);
- amplitude control sheets (R chart – fig. 12);
- control sheets for standard deviation of the sample "[6].

The average of these subgroups is under control, due to the fact that it does not violate any of the 14 rules presented in figure 3.

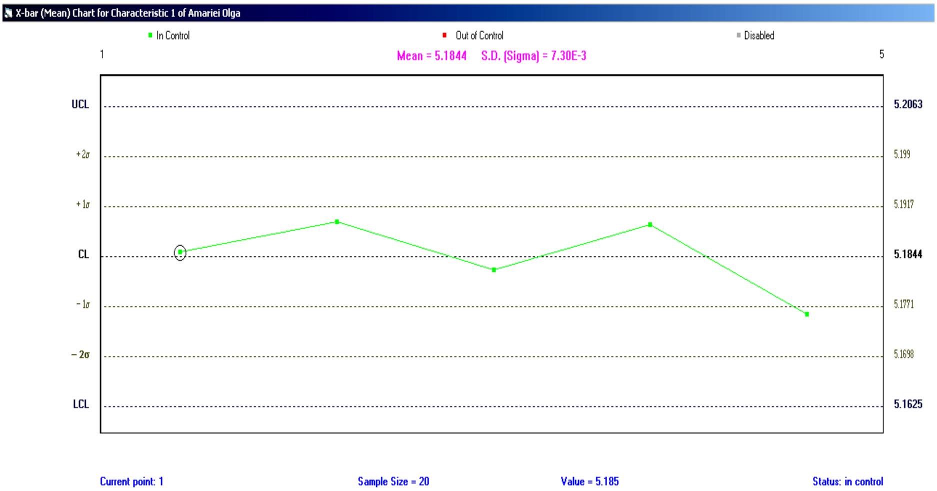


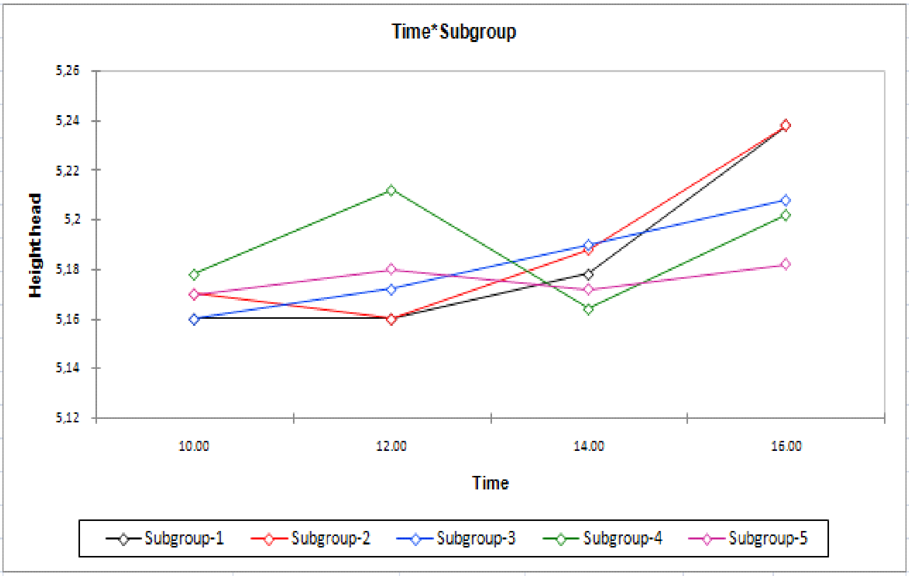
Figure 4. X-bar (Mean) Chart

In fig. 5 are presented the results provided by XLSTAT in tabular form, in fig. 6, in graphical form, as well as the descriptive statistical parameters (fig. 7).

Time\Subgroup	1	2	3	4	5
10.00	5,160	5,170	5,160	5,178	5,170
12.00	5,160	5,160	5,172	5,212	5,180
14.00	5,178	5,188	5,190	5,164	5,172
16.00	5,238	5,238	5,208	5,202	5,182

Subgroup\Time	10.00	12.00	14.00	16.00
1	5,160	5,160	5,178	5,238
2	5,170	5,160	5,188	5,238
3	5,160	5,172	5,190	5,208
4	5,178	5,212	5,164	5,202
5	5,170	5,180	5,172	5,182

Figure 5. Mean by time factor and subgroup factor, respectively by the subgroup factor



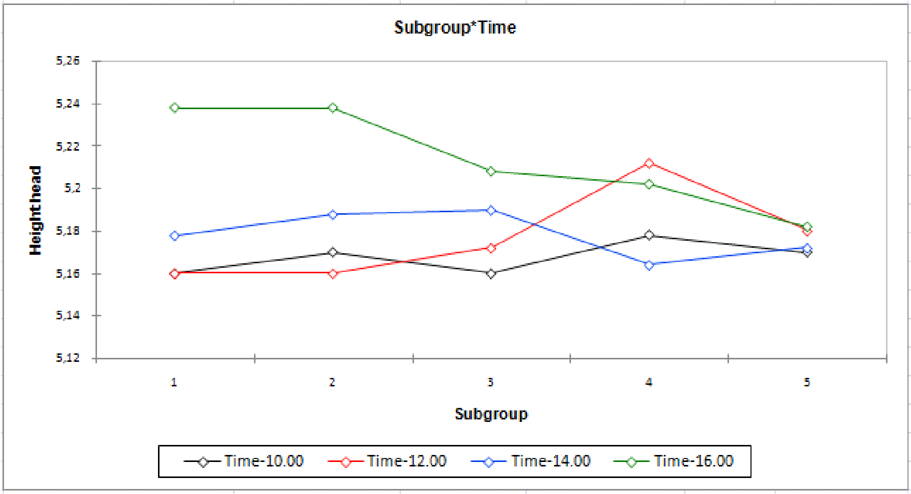


Figure 6. Graphic representation of the average/mean the time factor, rspectively by the subgroup factor

Statistiques descriptives (Données quantitatives) :

Statistique	Height head
Nb. d'observations	100
Minimum	5,130
Maximum	5,260
1er Quartile	5,150
Médiane	5,170
3čme Quartile	5,205
Moyenne	5,184
Variance (n-1)	0,002
Ecart-type (n-1)	0,041
Asymétrie (Pearson)	0,774
Asymétrie (Fisher)	0,786
Aplatissement (Pearson)	-0,734
Aplatissement (Fisher)	-0,709

Figure 7. Descriptive Statistics

The average estimated by the time factor is presented in matrix and graph form in fig. 8, and by the subgroup factor in fig. 9.

Modalité	Moyenne estimées	Erreur standard	Borne inférieure (95%)	Borne supérieure (95%)
10.00	5,168	0,007	5,153	5,182
12.00	5,177	0,007	5,162	5,192
14.00	5,176	0,008	5,161	5,191
16.00	5,214	0,007	5,199	5,228

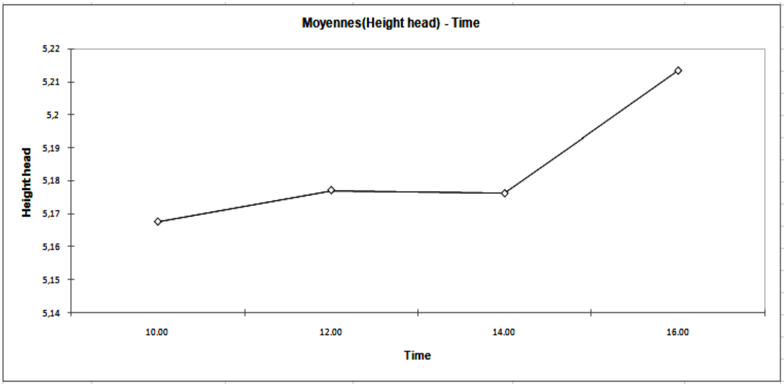


Figure 8. Estimated average by time factor

Modalité	Moyenne estimées	Erreur standard	Borne inférieure (95%)	Borne supérieure (95%)
1	5,184	0,008	5,167	5,201
2	5,190	0,008	5,173	5,206
3	5,183	0,008	5,166	5,199
4	5,189	0,008	5,172	5,206
5	5,173	0,009	5,156	5,190

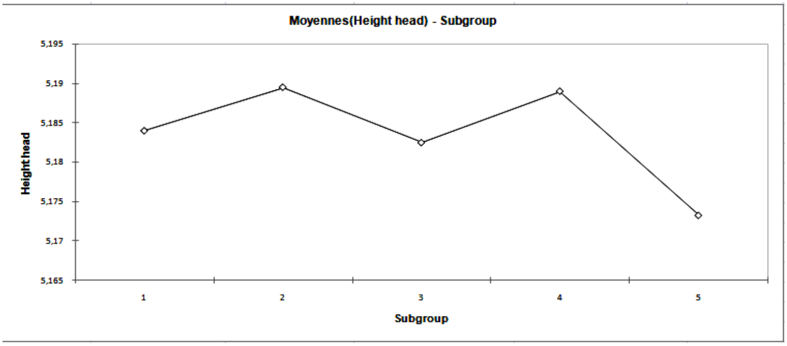


Figure 9. Estimated average by the subgroup factor

The CUSUM Chart for average diagram represents the dispersion of the average values from the central average value and has the role of highlighting the smallest deviations of the manufacturing processes. It is followed if from this point of view the values fall within normal limits, and in this case, due to the fact that all points are represented in green (fig.10), it results that there are no uncontrolled values, as in the case of the sheet control for environments (fig. 4).

It can be stated that "the CUSUM diagram is a" zoom "given to our process in order to better understand and observe its unnatural behaviors and to react in time to avoid waste from production" [5].

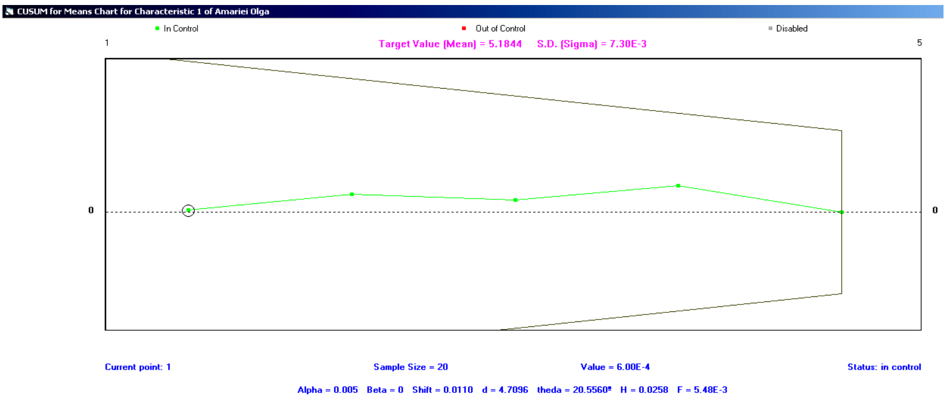


Figure 10. CUSUM for Mean Chart

In order to be able to follow "the evolution of a quality characteristic on which a single measurement is performed at a given time interval" [10], the X chart is used for individual values (fig.11).

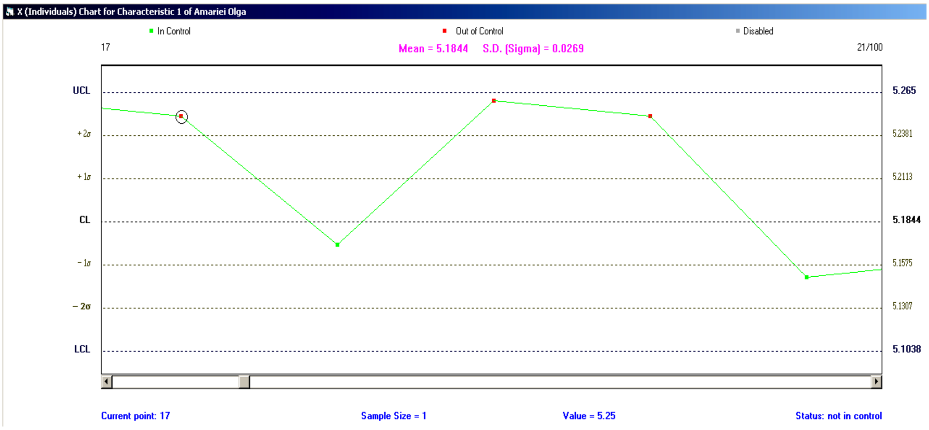


Figure 11. X (Individuals) Chart for points 17÷21

In Figure 11 it can be seen that points 17, 19 and 20 are out of control. But there are other parts out of control, and this can be seen in fig. 12.

The parts 8÷13, from 08.06.2020, ie the last three parts measured at 12 o'clock, as well as the first three, from 14 o'clock, violated rule 8 from the list of the 14 offered by the program. This is 8 Points in a Row Below CL, and this may be due to the following causes:

- incorrect adjustment of the machine;
- replacement of operators on machines;
- fatigue or inattention of operators when performing measurements.

Rule 3, namely: 2 of 3 Points Above 2 Sigma is violated by parts 17, 19, 20, (measurements also performed on 08.06.2020, but at 16 o'clock), 38÷40 (09.06.2020, 16 o'clock) , 58 (10.06.2020, 4 pm), 66÷68 (11.06.2020, 12 noon), 78 (11.06.2020, 4 pm) and 98 (12.06.2020, 4 pm), and parts 19, 20, 40 and 68 also violates rule 5, ie 4 of 5 Points Above 1 Sigma.

Single Point Jumps Down 2 Sigma - rule 14 violated by marks 79 (11.06.2020, 4 pm) and 99 (12.06.2020, 4 pm), and this may be due to the following causes:

- power failure
- tool breakage
- interruption of the supply of raw material
- calculation error etc.

	00:07:08		07-20-2021
Sample	Value	Status	Rule Violation
1	5.1700	In control	No rule violated
2	5.1500	In control	No rule violated
3	5.1600	In control	No rule violated
4	5.1700	In control	No rule violated
5	5.1500	In control	No rule violated
6	5.1500	In control	No rule violated
7	5.1700	In control	No rule violated
8	5.1500	Not in control	8
9	5.1600	Not in control	8
10	5.1700	Not in control	8
11	5.1700	Not in control	8
12	5.1500	Not in control	8
13	5.1700	Not in control	8
14	5.2000	In control	No rule violated
15	5.2200	In control	No rule violated
16	5.2600	In control	No rule violated
17	5.2500	Not in control	3
18	5.1700	In control	No rule violated
19	5.2600	Not in control	3 5
20	5.2500	Not in control	3 5
21	5.1500	In control	No rule violated
22	5.1600	In control	No rule violated
23	5.1800	In control	No rule violated
24	5.1700	In control	No rule violated
25	5.1900	In control	No rule violated

	00:07:08		07-20-2021
Sample	Value	Status	Rule Violation
26	5.1900	In control	No rule violated
27	5.1700	In control	No rule violated
28	5.1500	In control	No rule violated
29	5.1600	In control	No rule violated
30	5.1400	In control	No rule violated
31	5.1300	In control	No rule violated
32	5.1900	In control	No rule violated
33	5.1900	In control	No rule violated
34	5.2600	In control	No rule violated
35	5.1700	In control	No rule violated
36	5.1700	In control	No rule violated
37	5.2600	In control	No rule violated
38	5.2500	Not in control	3
39	5.2600	Not in control	3
40	5.2500	Not in control	3 5
41	5.1700	In control	No rule violated
42	5.1500	In control	No rule violated
43	5.1600	In control	No rule violated
44	5.1500	In control	No rule violated
45	5.1700	In control	No rule violated
46	5.1900	In control	No rule violated
47	5.1900	In control	No rule violated
48	5.1700	In control	No rule violated
49	5.1500	In control	No rule violated
50	5.1600	In control	No rule violated

	00:07:08		07-20-2021
Sample	Value	Status	Rule Violation
51	5.1500	In control	No rule violated
52	5.1600	In control	No rule violated
53	5.2600	In control	No rule violated
54	5.1900	In control	No rule violated
55	5.1900	In control	No rule violated
56	5.1600	In control	No rule violated
57	5.2600	In control	No rule violated
58	5.2500	Not in control	3
59	5.2000	In control	No rule violated
60	5.1700	In control	No rule violated
61	5.1500	In control	No rule violated
62	5.1600	In control	No rule violated
63	5.1700	In control	No rule violated
64	5.1700	In control	No rule violated
65	5.2400	In control	No rule violated
66	5.2400	Not in control	3
67	5.2600	Not in control	3
68	5.2500	Not in control	3 5
69	5.1500	In control	No rule violated
70	5.1600	In control	No rule violated
71	5.1400	In control	No rule violated
72	5.1300	In control	No rule violated
73	5.1700	In control	No rule violated
74	5.1900	In control	No rule violated
75	5.1900	In control	No rule violated

	00:07:08		07-20-2021
Sample	Value	Status	Rule Violation
75	5.1900	In control	No rule violated
76	5.2300	In control	No rule violated
77	5.2600	In control	No rule violated
78	5.2500	Not in control	3
79	5.1400	Not in control	14
80	5.1300	In control	No rule violated
81	5.1700	In control	No rule violated
82	5.2200	In control	No rule violated
83	5.1500	In control	No rule violated
84	5.1600	In control	No rule violated
85	5.1500	In control	No rule violated
86	5.2200	In control	No rule violated
87	5.1700	In control	No rule violated
88	5.1700	In control	No rule violated
89	5.1500	In control	No rule violated
90	5.1900	In control	No rule violated
91	5.1900	In control	No rule violated
92	5.1500	In control	No rule violated
93	5.1600	In control	No rule violated
94	5.2200	In control	No rule violated
95	5.1400	In control	No rule violated
96	5.1300	In control	No rule violated
97	5.2600	In control	No rule violated
98	5.2500	Not in control	3
99	5.1400	Not in control	14
100	5.1300	In control	No rule violated

Figure 12. Matrix results

We move on to the verification of the inclusion in the accepted minimum and maximum limits of the average values on subgroups, ie R (Range) chart – figure 13.

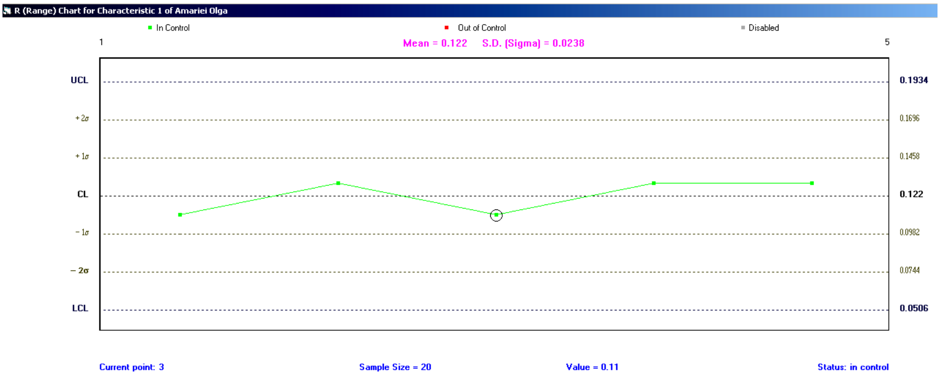


Figure 13. R (Range) chart

Figure 14 shows the CUSUM for range chart. According to R chart and CUSUM for range chart, all subgroups fall within the required limits.

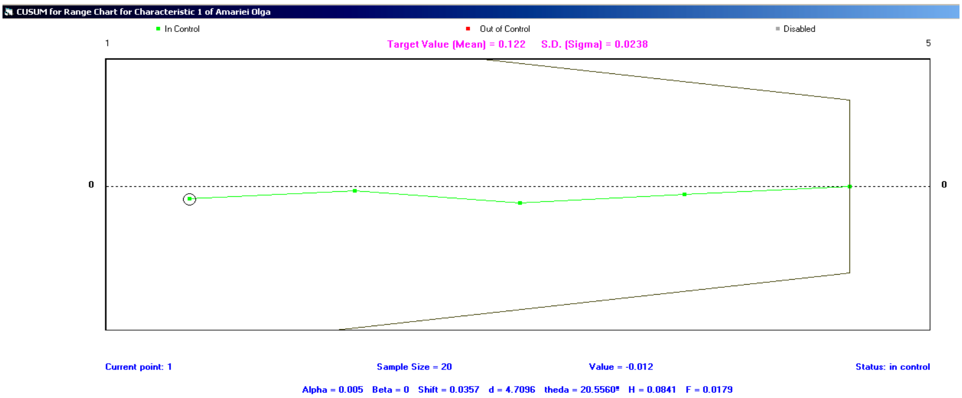


Figure 14. CUSUM for Range Chart

4. Conclusion

The average of the subgroups is under control, due to the fact that it does not violate any of the 14 rules predefined by the WinQSB program module. Also, the CUSUM Chart for Mean diagram, which represents the dispersion of the average values from the central average value and has the role of highlighting the smallest deviations of the manufacturing processes, shows that there are no uncontrolled values, as in the case of the control for environments. The verification of the inclusion in the accepted minimum and maximum limits of the average values by subgroups led to the same conclusion, namely that all subgroups fall within the required limits.

Regarding the X diagram for individual values, it is observed that out of the 100 parts that are the subject of this study, 20 violate one or even two rules (tests) offered by the program. Most of the measured parts that violate these rules are from the samples at 12 o'clock, namely parts, after the lunch break or at 4 o'clock (11 parts), before the end of the activity on that day.

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