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Statistical Control of the Assembly Process of Gun Cabinet

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***Abstract*—A statistical analysis of the assembly process of gun cabinets produced in 2017 was done based on the available documentation of the company "PRIMAT OPREMA" DOO Baljevac. After checking the stability of the process using the control charts for attributes, the analysis of the number and selection of impact defects with the help of Pareto analysis was carried out and corrective and preventive measures for quality improvement are proposed.**

***Keywords*— improvement of quality, statistical control, c-chart, Pareto analysis, gun cabinets**

I. INTRODUCTION

Statistical control takes a very significant place in the process of quality improvement. The beginning of the application of statistical methods was related to the beginning of the 20th century, while their more intensive application began only during the Second World War at the time of organizing mass production. Statistical methods help to direct control of the technological and business processes to those factors that get the most impact on these processes. Based on this, it can be concluded which corrective measures should be taken to ensure stable and satisfactory quality [1,2,3].

This paper presents the procedure for testing the stability of the assembly process of gun cabinets from the product range of company Primat Oprema doo, Baljevac using the control charts for attributes, the classification and selection of the most numerous defects using the Pareto analysis and solutions were proposed to improve the quality of the production process.

II. GUN CABINETS

"Primat OPREMA DOO" company - Baljevac produces security equipment used to keep safe preciousness such as important documents, money, jewellery etc [4,5]. All security equipment is certified by the German Institute VdS, according to European standard EN 1143-1. In addition to safety equipment, this company also manufactures gun cabinets designed to hold long-range weapons of the models TS-1 and TS-2 (Figure 1).

The cabinet body and door are of single-wall design, made of high quality steel sheet. The cabinets are able to be secured to the floor (4 holes) and to the wall (2 holes). Safety locks -grade A, according to EN 1300 are used for locking the cabinets. Model TS-1 is equipped with a weapon holders for 7 guns, 4 door boxes at the inner side of the door, and the TS-2 model is equipped with weapon holders for 9 guns, 4 door boxes at the inner side of the door and 1 shelf. The basic characteristics of the design are given in Table 1.

Fig. 1 Gun cabinets model TS-1 and model TS-2 [5]

TABLE I BASIC CHARACTERISTICS OF GUN CABINETS MODEL TS-1 AND MODEL TS-2 [5]

Model	External dimensions HxWxD / mm	Internal dimensions HxWxD / mm	Weapon holders max. capacity	Weight approx. kg
TS - 1	1250x300x285	1224x292x221	7	63
TS - 2	1500x380x285	1474x372x221	9	84

III. STATISTICAL CONTROL OF THE ASSEMBLY PROCESS

A. *Defect clasification*

"PRIMAT OPREMA" DOO Company - Baljevac uses QMS to complied with the requirements of ISO 9001: 2008. Product control and the way of recording the results is carried out by a control procedure that implies the use of control charts for attributes and Pareto analysis. The control plan defines 10 defects to be controlled by 100%. (Table 2).

TABLE II CLASSIFICATION OF DEFECTS ON CABINETS TYPE TS-1 AND TS-2

Defect name	designation
Protection of the roof latch	G1
Alignment of the roof and the case of the shell	G2
Welding corners on the roof	G3
Welding the bottom in the corners-from the outside	G4
The clearance between the casing and the door	G5
Alignment of the door and the case	G6
Flatness of the sides	G7
Grinding all visible welds in the door and the case	G8
Complete fusion of the plate holder	G9
Complete fusion and presence of door elements	G10

B. Process stability analyses

Data on the number of detected defects are shown in Tables 3 and 4. The tables have been used to collect the total number of defects. The resulting values are shown in the last column of the table.

The c - chart for number of defects was used to evaluate the stability of the process. The value of the central line for the c-chart for the TS-1 is [1-3,6]:

$$CL_C = \overline{c} = \frac{1}{s}\sum_{i=1}^{s} c_i = \frac{37}{20} = 1{,}85 \quad (1)$$

where:
s – the number of unit examined (s=20);
c_i –the number of defects on the i-th unit.
Control limits are:

$$GKG_C = \overline{c} + 3\cdot\sqrt{\overline{c}} = 5{,}93$$
$$DKG_C = \overline{c} - 3\cdot\sqrt{\overline{c}} = 0{,}00 \quad (2)$$

Limits of zone "A" (area between second and third standard deviations) and "B" (range between first and second standard deviations) are [6]:

$$\overline{c} + 2\cdot\sqrt{\overline{c}} = 4{,}57$$
$$\overline{c} + 1\cdot\sqrt{\overline{c}} = 3{,}21$$
$$\overline{c} - 2\cdot\sqrt{\overline{c}} = 0{,}00 \quad (3)$$
$$\overline{c} - 1\cdot\sqrt{\overline{c}} = 0{,}49$$

TABLE III STATISTICAL DATA FOR GUN CABINET MODEL TS-1

Defects	Sample number																				Σ
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
G1																					0
G2																					0
G3																					0
G4																					0
G5		1			1		1				1		1		1	1				1	8
G6	1		1	1	1		1	1			1	1	1	1		1		1			12
G7	1						1	1		1	1	1	1		1	1			1		10
G8			1				1	1		1			1	1	1						7
G9																					0
G10																					0
Σ	**2**	**1**	**2**	**1**	**2**	**0**	**4**	**3**	**0**	**2**	**3**	**2**	**4**	**2**	**3**	**3**	**0**	**1**	**1**	**1**	**37**

TABLE IV STATISTICAL DATA FOR GUN CABINET MODEL TS-2

Defects	Sample number																				Σ
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
G1																					0
G2																					0
G3																					0
G4																					0
G5	1	1							1	1			1			1	1				7
G6	1	1		1	1				1	1	1	1	1	1					1	1	12
G7																1					1
G8	1						1	1								1					4
G9														1							1
G10																					0
Σ	**3**	**2**	**0**	**1**	**1**	**0**	**1**	**1**	**2**	**2**	**1**	**1**	**2**	**2**	**0**	**3**	**1**	**0**	**1**	**1**	**25**

The design of the "c" chart with the drawn central line, control limits and warning limits shows that all the points are within the control limits (Figure 2) and that all 4 rules for the stability evaluation of the process [6] have been respected and that the observed process could be considered controlled, ie stable.

The value of the central line for the c-chart for the cabinet model TS-2 is:

$$CL_C = \overline{c} = \frac{1}{s}\sum_{i=1}^{s} c_i = \frac{25}{20} = 1{,}25 \quad (4)$$

Control limits are:

$$GKG_C = \overline{c} + 3 \cdot \sqrt{\overline{c}} = 4,60$$
$$DKG_C = \overline{c} - 3 \cdot \sqrt{\overline{c}} = 0,00 \quad (5)$$

Limits of zone "A" (area between second and third standard deviations) and "B" (range between first and second standard deviations) are:

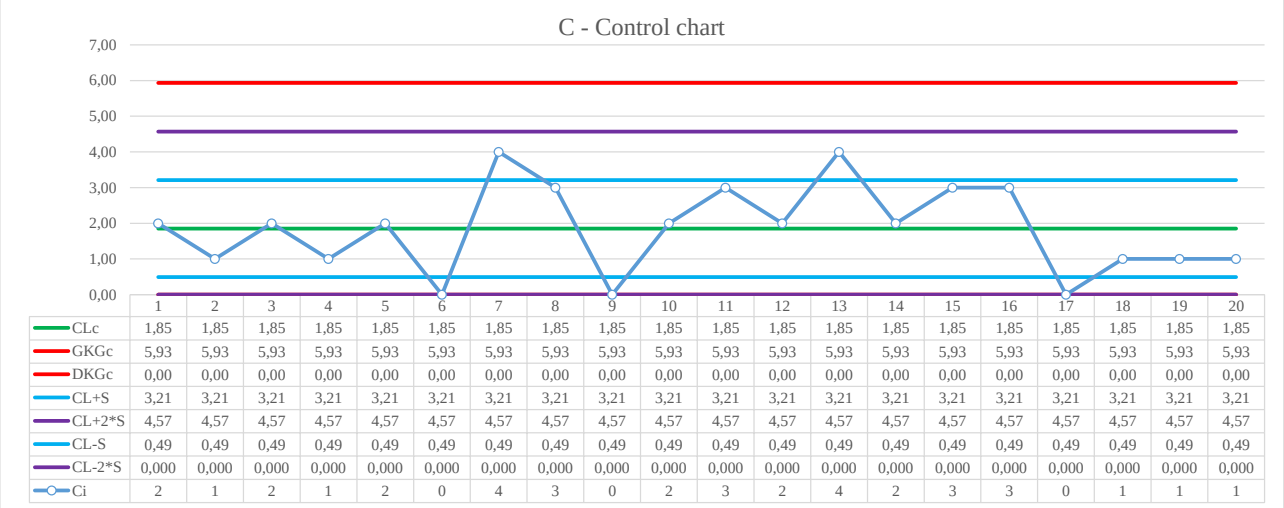
$$\overline{c} + 2 \cdot \sqrt{\overline{c}} = 3,49$$
$$\overline{c} + 1 \cdot \sqrt{\overline{c}} = 2,37$$
$$\overline{c} - 2 \cdot \sqrt{\overline{c}} = 0,00 \quad (6)$$
$$\overline{c} - 1 \cdot \sqrt{\overline{c}} = 0,13$$

The design of the "c" chart with the drawn central line, control limits and warning limits shows that all the points are within the control limits (Figure 3) and that all 4 rules for the stability evaluation of the process have been respected and that the observed process could be considered controlled, ie stable.

C. Pareto analyses

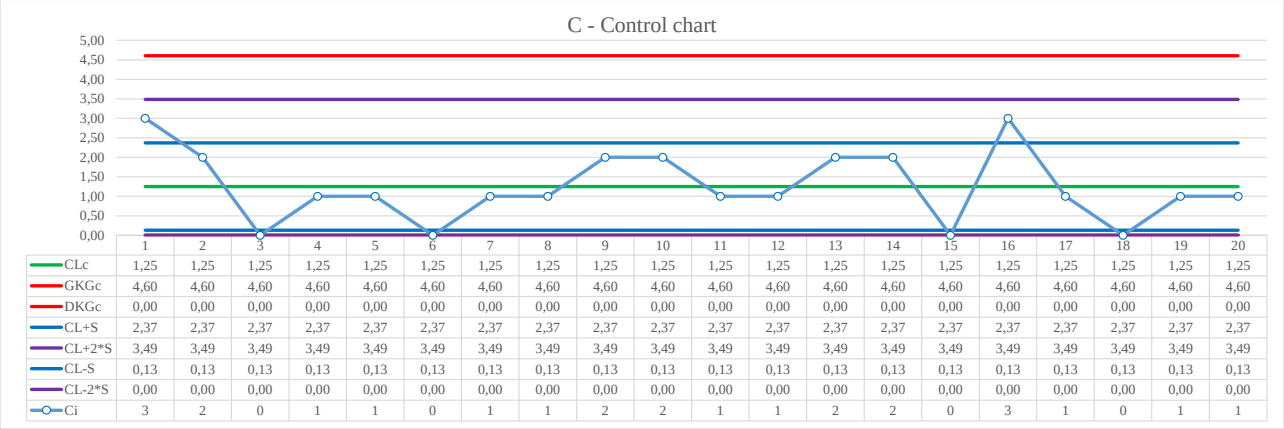
Pareto analysis was used to select the influential defects [7]. By classifying the defects according to the number of occurrences for the cabinet model TS-1, the Table 5 that shows the defects classified in two groups (Figure 4) is obtained:

- group A that encompasses 81,08% of all defects
- group B that encompasses 18,92 % of all defects



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
CLc	1,85	1,85	1,85	1,85	1,85	1,85	1,85	1,85	1,85	1,85	1,85	1,85	1,85	1,85	1,85	1,85	1,85	1,85	1,85	1,85
GKGc	5,93	5,93	5,93	5,93	5,93	5,93	5,93	5,93	5,93	5,93	5,93	5,93	5,93	5,93	5,93	5,93	5,93	5,93	5,93	5,93
DKGc	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
CL+S	3,21	3,21	3,21	3,21	3,21	3,21	3,21	3,21	3,21	3,21	3,21	3,21	3,21	3,21	3,21	3,21	3,21	3,21	3,21	3,21
CL+2*S	4,57	4,57	4,57	4,57	4,57	4,57	4,57	4,57	4,57	4,57	4,57	4,57	4,57	4,57	4,57	4,57	4,57	4,57	4,57	4,57
CL-S	0,49	0,49	0,49	0,49	0,49	0,49	0,49	0,49	0,49	0,49	0,49	0,49	0,49	0,49	0,49	0,49	0,49	0,49	0,49	0,49
CL-2*S	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Ci	2	1	2	1	2	0	4	3	0	2	3	2	4	2	3	3	0	1	1	1

Fig. 2 C-chart for cabinet model TS-1



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
CLc	1,25	1,25	1,25	1,25	1,25	1,25	1,25	1,25	1,25	1,25	1,25	1,25	1,25	1,25	1,25	1,25	1,25	1,25	1,25	1,25
GKGc	4,60	4,60	4,60	4,60	4,60	4,60	4,60	4,60	4,60	4,60	4,60	4,60	4,60	4,60	4,60	4,60	4,60	4,60	4,60	4,60
DKGc	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
CL+S	2,37	2,37	2,37	2,37	2,37	2,37	2,37	2,37	2,37	2,37	2,37	2,37	2,37	2,37	2,37	2,37	2,37	2,37	2,37	2,37
CL+2*S	3,49	3,49	3,49	3,49	3,49	3,49	3,49	3,49	3,49	3,49	3,49	3,49	3,49	3,49	3,49	3,49	3,49	3,49	3,49	3,49
CL-S	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13
CL-2*S	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Ci	3	2	0	1	1	0	1	1	2	2	1	1	2	2	0	3	1	0	1	1

Fig. 3 C-chart for cabinet model TS-2

By classifying the defects according to the number of occurrences for the cabinet model TS-2, the Table 5 that shows the defects classified in three groups (Figure 5) is obtained:

- group A that encompasses 76,00 % of all defects
- group B that encompasses 20,00 % of all defects
- group C that encompasses 4,00 % of all defects

From the Pareto analysis, it can be seen that only 4 of the 10 different defects for TS-1 only 4 appear and for TS-2 only 5 defects appear, which is the result of continuous monitoring of the quality of these products and constant efforts to improve the process of assembling.

It can be stated that the most numerous defects are:

- G6 – Alignment of the door with the case 32,43%
- G5 – Clearance between the case and the door (21,62% and 28%)
- G8 – Weld spatter (18,92% and 16%)
- G5 – Flatness of the sides (27,03% and 4%)

and they need to be paid special attention to, in order to improve product quality.

TABLE V CLASSIFICATION OF DEFECTS BY NUMBERS FOR CABINET MODEL TS-1

TS-1					
Gi	**ci**	**Σ**	**c_i (%)**	**Σ (%)**	**Group**
G6	12	12	32.43%	32.43%	**A**
G7	10	22	27.03%	59.46%	
G5	8	30	21.62%	81.08%	
G8	7	37	18.92%	100.00%	**B**
G1	0	37	0.00%	100.00%	**C**
G2	0	37	0.00%	100.00%	
G3	0	37	0.00%	100.00%	
G4	0	37	0.00%	100.00%	
G9	0	37	0.00%	100.00%	
G10	0	37	0.00%	100.00%	
Σ	**37**				

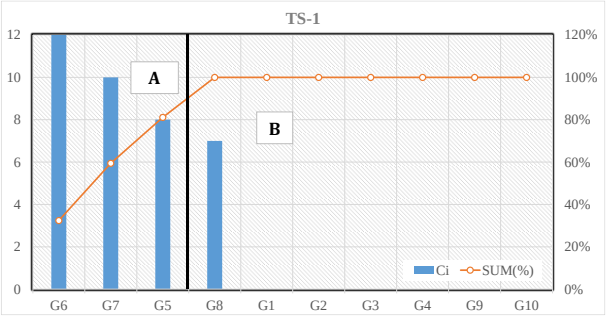


Fig. 4 Pareto diagram for cabinet model TS-1

TABLE VI CLASSIFICATION OF DEFECTS BY NUMBERS FOR CABINET MODEL TS-2

TS-2					
Gi	**ci**	**Σ**	**ci (%)**	**Σ (%)**	**Group**
G6	12	12.0	48.00%	48.00%	**A**
G5	7	19.0	28.00%	76.00%	
G8	4	23.0	16.00%	92.00%	**B**
G7	1	24.0	4.00%	96.00%	
G9	1	25.0	4.00%	100.00%	**C**
G1	0	25.0	0.00%	100.00%	
G2	0	25.0	0.00%	100.00%	
G3	0	25.0	0.00%	100.00%	
G4	0	25.0	0.00%	100.00%	
G10	0	25.0	0.00%	100.00%	
Σ	**25**				

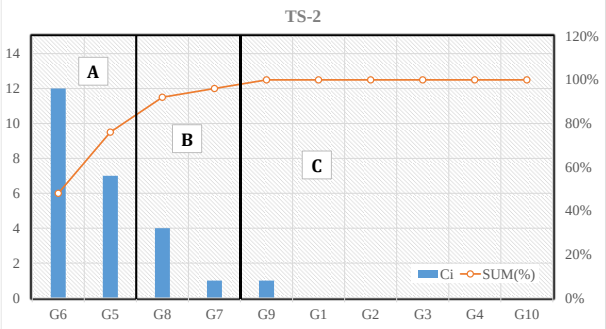


Fig. 5 Pareto diagram for cabinet model TS-2

IV. QUALITY IMPROVEMENT PROPOSITION

Knowing the status of the company "Primat oprema" DOO, insufficient training of the workers and the lack of quality workforce can be pointed out as a basic problem. Given the constant fluctuation of workers and the inability to provide quality workforce, training of workers in the company "PRIMAT OPREMA" DOO, Baljevac is performed continually. The problem is the inadequate number of instructors and the constant "urgency" of work orders, which is why this activity cannot always be carried out sufficiently well.

Although there are guidelines for all operations for gun cabinet assembly process, it is desirable to upgrade the operation list by adding visualizations of individual operations next to the description of the process. However, quality and technology engineers are left out to carefully consider the advanced analysis and preventive and corrective measures to be taken to improve the quality of the gun cabinet assembly process.

V. CONCLUSIONS

The conducted analysis has shown that the process of assembling of cabinets type TS-1 and TS-2 is stable but there are also significant possibilities for its improvement if special attention is paid to eliminating factors affecting the most numerous defects.

This confirms the correctness of the applied statistical methods and quality tools and the application of the proposed solutions will ensure the improvement of the quality system in the assembly process of gun cabinets, reduce the cost of quality and provide greater market competitiveness.

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