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# DETERMINING THE CAUSE OF DEVIATION IN FEED SYSTEMS SOFT DRINKS APPLYING PARETO METHODS

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## Abstract

One of the most important standards approaching process quality is ISO 9001, which is based on 8 principles. Therefore, the measurement, testing, analysis, and process capability basis are usually used for assessment of the achieved quality level, and can be utilized for improvement of processes and products quality. This paper presents the essence and significance of the process approach and methodology of testing, analysis and assessment process as the basic assumptions in quality improvement process.

The emphasis is on basic indicators of process capability index potential (scatter) and ability (adjustment) process. Using the software package QI Macros, quality index of the production process of non-alcoholic carbonated beverages in serial production is determined. Our aim was to shown the need of applying the Pareto analysis, quality system statistical tool for ranking the errors that lead to deviations in the system of soft drink "Orangina" filling, and to make recommendations an implementation of corrective actions based on the indices are priorities. The main objectives of the work was to determine the causes of deviations in soft drink filling system with different groups of samples (filling of 0.5, 1.0, 1.25 and 1.5 liters), and to establish whether application of recognized methods for determination of level of process control (calculating the index of resources (Cp) and capability indices (Cpk)) can determine whether the whole process is under control. Examined processes of filling in the brewery were working on 3 sigma level.

The results showed that the maximum deviation occurs when the group of samples with a volume of 1.5 liters are filling. On the other hand, a group of samples of 0.5 liters showed the most accurate and statistically the most appropriate index values Cp and Cpk. Pareto method proved that the four groups of causes (needles soaking juice, heating with blowers bottle, the pressure in the carousel and calibration) cause the greatest number of defects (78.1%).

***Key words**: Process approach, Ability to process, Index potential, Capability index.*

## 1. Introduction

The process of bottling is the last step in the soft drinks production, which brings them a distinctive look, and above all makes its aroma and specific flavor intact. Filling process is made up from a large number of operations relating to the manipulation of the juice which is mostly because of the filler, and the filler in the cylinders. During this filing process, it is necessary to take into account a number of factors that should be carried out in the desired direction, or they should be performed in a way that there will be no problems that may affect the quality of the finished product.

Manufacturers must keep in mind that their processes are capable to meet the requirements. For this purpose it is necessary processes to be controlled and to monitor all parameters related to the filling process, which will prevent or reduce to a minimum the potential causes for deviation. According to regulation of refreshing soft drinks and similar products [1], the permitted deviation from the declared weight are as following:

from 200 - 500 g ± 10 g or above 0.4 to 1 L ± 2% and

from 500 - 5,000 g ± 20 g or above 1 to 2 L ± 1.5%.

The main objective of this study was to determine whether there is a deviation in the soft drink filling system and if so, what is the cause? In order to determine whether the whole process is under control usually are used recognized methods for determining the level of process control - calculating potential index (Cp) and capability index (Cpk).

Total quality management (TQM) is a management approach that includes long-term orientation towards continuous improvement of the quality that will meet and exceed customer expectations [2]. Total quality management is a mean for personal efficiency and performance improvement, and for coordination and direction of all individual efforts within the entire organization. It provides a framework within which it can be carried out continuous improvement [3].

Lean Sigma is the most effective method for the management of quality criteria in line with business objectives. It is a method to improve business performance, and each of the major standards for food quality such as HACCP, ISO 9001, ISO 22000, ISO 14001, etc., benefit from the continuous improvement which this method brings. With these standards as a starting point it is easy to incorporate Lean Sigma approach to the different quality management systems [4].

In order to achieve the best quality of products with the least cost, the question is posed by all organizations. One of the possible ways that today there are more supporters of the application 6σ methodology. It is a business methodology, which aims to almost completely eliminate errors in each product, service and production process. It was first used in Motorola to reduce errors in the production of electronic components and devices. Although the original methodology focused on manufacturing processes, today applied in the processes related to marketing, purchasing, finance, service, and so on [5].

According to the Ozlem and Hakan [6], the most common statistical definition of Six Sigma program is as follows: Six Sigma means 99.9996% success. This level of success (perfection) is equivalent to the occurrence of non-compliance of 3.4 per million opportunities (eng. DPMO - defects per million opportunities). The basis of Lazic [7] Six Sigma methodology is the DMAIC cycle (Define, Measure, Analyze, Improve and Control). Also, as Six Sigma methodology often is used and DMADV cycle (Define, Measure, Analyze, Design and Verification) [8]. For Sigma (σ) is said to be, among other things, the tool for process ability measurement. This variation occurs in each manufacturing process and regardless of the process automation [9, 10].

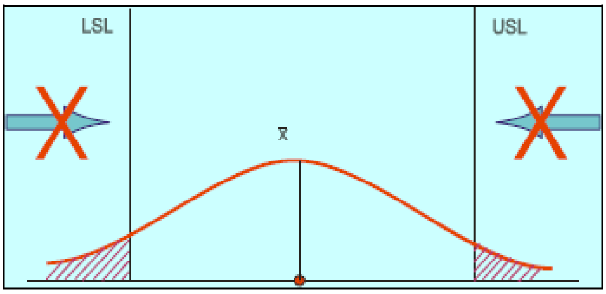

**Figure 1. Distribution within the limits of U - L. (http://www.biblio.irb.hr/prikazi-rad?&rad=481671)**

## 2. Materials and Methods

The research was done in Bihac Brewery Inc. in the period from April to June 2012. Samples required for the development work were collected at the technological line production of carbonated soft drinks Orangina and Limona on the process step for charging.

The samples used in the work are divided into five groups:

- Group I - soft drinks bottled in PET bottles of 0.5 L
- Group II - soft drinks bottled in PET bottles of 1.0 L
- Group III - soft drinks bottled in PET bottles of 1.25 liters
- Group IV - soft drinks bottled in PET bottles of 1.5 liters

Samples were taken periodically from the filling line at intervals of 30 minutes to 1 hour. For each group was carried out by 500 measurements over a period of several days, depending on the production plan for the group of samples:

*Group I - bottle of 0,5 L - Orangina*
Samples has been taken in the period from 18.04.-19.04. 2012. During this period, from the line were taken 500 samples from 99,625 bottles produced in the same period.

*Group II - bottle of 1,0 L - Limona*
Samples were taking during the period from 25.04. - 26.04. 2012, when the 500 samples taken from 52,533 bottles produced during this period.

*Gruop III - bottle of 1,25 L - Orangina*
Samples were taking during the period from 16.04. - 07.05. 2012, when the from the filling lines of 500 samples taken from 48,390 bottles produced during this period.

*Group IV - bottle of 1,5 L - Orangina*
Samples were taking during the period from 17.04. - 10.05. 2012. On the line was taken 500 samples from 41,344 bottles produced during this period.

a) Potential Capability - Cp

Index potential process Cp indicates the precision and scattering process, and is often called the index of precision. Depending on the value of Cp process is evaluated as [7]:

- imprecise CP1,
- critically precise $1 < Cp < 1.33$ in
- precise $Cp \geq 1.33$.

The amount of index Cp directly indicates whether if process is capable. What is the amount of index higher to a lower dissipation of the process. In developed countries today are required to the minimum value of the index Cp is 1.33. This request the company raise up to 1.67, or the Cp ≥ 2 [11, 12].

b) Capability Ratio Cr

The amount of this index is the reciprocal value of the index Cp and Cr = 1 / Cp. If the amount of this index shows the percentage obtained by the percentage of the tolerance area that is "used" range of processes. To make the process more capable, the amount of Cr index should be less than 1 [7, 13, and 14].

The results are entered and processed in Excel. For statistical data analysis obtained by the measurements we used software package Excel SPC Software - QI Macros by which the calculations of the index potential (Cp) and the capability indices (Cpk) process and other indicators of process capability (CPU, CPL, CPM Pp. PPK, etc.) were performed.

## 3. Results and Discussion

### 3.1 Results

In accordance with the aim to determine whether there are and the causes of deviations in the system of soft drinks filling, the study is divided into four groups of soft drinks according to the volume of samples From the obtained data it is evident that the process has a high standard deviation (4.5581), for first group, ie the range between the minimum (461.56 mL) and maximum (506.95 mL) measured a large capacity and is 45,39 mL. These results are indicating low values of Cp and Cpk. Calculations of indices of potential processes (Cp), process capability indices (Cpk), and other indicators of process capability graphically are shown in histogram in Figure 2.

Indicators process performances in first group amounted Pp = 0.73 and Ppk = 0.53, which indicates unadjusted of the feeding process. A preliminary assessment of the ability of the process is carried out at the beginning of the process or after a relatively short time monitoring of feeding process.

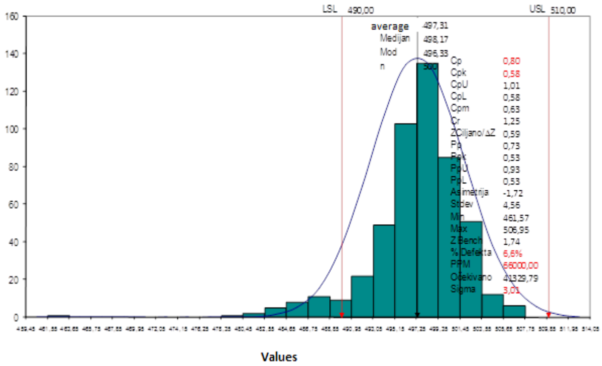

Figure 2. Histogram for first group of samples 0,5 L

Contrary to previous group of samples (0.5 l) in the second group, the results indicate that the deviations in the measured values of volume were lower (sd - 3.2983). Range between the minimum and maximum volume was lower (23, 76 mL), which indicates a better adjustment of the feeding process.

Results Cp and Cpk calculations and other indicators of process capability are shown in the Figure 3. Data presented in the histogram, may suggest that the process is precise but still unadjusted enough.

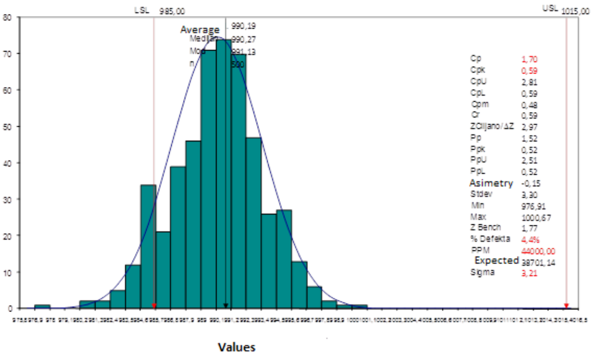

Figure 3. Histogram for second group of samples 1L

Indicators process performances Pp = 1.52 and Ppk = 0.52 which indicates unadjusted of the feeding process. Same like in first group in the second group ability of the process is carried out at the beginning of the process andf after a relatively short time monitoring of feeding process.

Obtained results indicate that the process of filling beverage volume 1.25 liters meets the requirements prescribed by the Law on refreshing soft drinks and similar products [1], according to which the tolerance of the declared volume of 1.0 to 2.0 L ± 1.5%, which in this case amounts to 18.75 mL. The value of the standard deviation was high (4.1053), that was a large range between the minimum (1207.63 mL) and maximum volume (1244.81 mL), which is 37.18 mL, indicating a rather large dispersion of feeding process. In this group of samples can be noted that both the minimum and maximum value, and the mean volume below the target value.

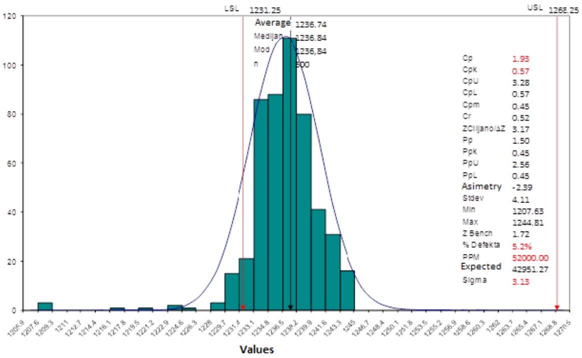

Figure 4. Histogram for third group of samples 1.25 L

Indicators of process capability for a longer period of feeding time were Cp = 1.93 and Cpk = 0.57 and are classified into the category of the test process precise and still unadjusted (Figure 4). The process is capable as meet the required specification (LSL and USL) with only 5.2% of the defect (samples outside the limits of the specification). This is supported by the value of the ratio capabilities Cr = 0.48 (less than 1 is desirable).

Inaccurate process (which can be seen on the histogram) demonstrate the values obtained CPL and CPU (0.57 and 3.28) that are different (for absolute adjusting of process, it is necessary that these values are the same), and point to the already established fact that the values for obtained volume absolutely tend to bottom limit of specification (LSL = 1231.25).

The value of the index performance amount Pp = 1.50 and Ppk = 0.45, which indicates the inability of the process.

Also in this group of samples we can notice very high standard deviation of volume (3.7542) and that the median value of the volume (1478.13) is below the target value (1.500 mL), which indicates that the process tends to absolute lower limit specifications. Of course, it indicates inaccurate process as was the case with the previous group of samples.

Based on the data presented in the histogram it is evident that the scattering process is beyond the boundaries of the specification (LSL lower and upper limits of tolerance USL), which is the first sign that the process is not capable. Based on the value of the indicator ability (potential index of process Cp = 2.63> 1.33 and the capability index Cpk = 0.07 <1.33 have a very low value), it is evident that the process of filling soft drink 1.5 L belongs to the group precise and inaccurate process (Figure 5).

Indexes of process performances are Pp = 2,0i PPK = 0.06, also indicate the precision and misalignment process.

Indexes CPU = 5.18 and = 0.07 CPL indicate inaccurate process which is obvious as can be seen from the histogram. It is evident that the measured volume tend to have lower limit specifications, and to exceed the lower limit of the specifications.

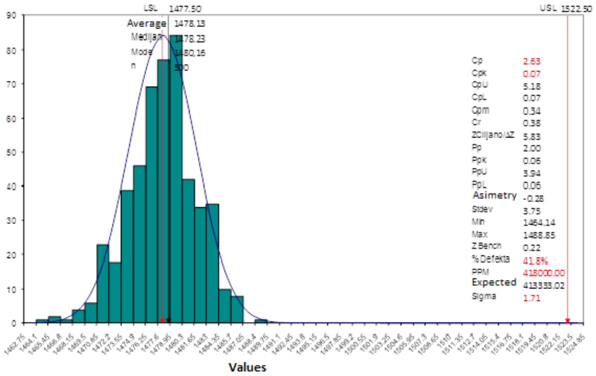

**Figure 5. Histogram for fourth group of samples 1.5 L**

### *3.1.1 Determining the causes of deviations in the system charging drinks*

Monitoring charging process within these four groups of samples in the same period, in which the samples were taken to measure the volume, we established certain problems that have affected or could affect the volume of finished products. All the factors which determine the volume of finished product, and the level of accuracy of the system for filling bottles.

First group 0.5 L: All deviations of volume in this group (Figure 6) were influenced by: changing needles (47 bottles), clogging nozzles with needles and vacuum (36 bottles), pressure drop in the carousel (22 bottles), overtemperature drink (14 bottles), and inaccurate filling hat, control (14 bottles), calibration (10 bottles), human error (9 bottles), distortion pins (0 bottle), and flat bottom with the bottle (0 bottle).

Group two 1.0 L: Pareto for the group of samples filled in bottles of 1.0 liter is displayed in Figure 7. In the second group of samples defect percentage is only 4.4%. In the Figure 7 is obvious that there has been 49 defects.

At deviation of volume in this group was influenced by: distortion pins (19 bottles), inaccurate filling hat control (11 bottles), changing needles (6 bottles), over temperature of beverages (5 bottles), calibration (5 bottles), human error (3 bottles), clogging nozzles on vacuum needles (0 bottles), pressure drop in the carousel (0 bottle), and flat bottom of the bottle (0 bottle).

Group three 1.25 L: Pareto diagram for a group of samples of filled in bottles of 1.25 L is shown in Figure 8. The percentage of the defect at group was 5.2%. In total 162 defects were reported.

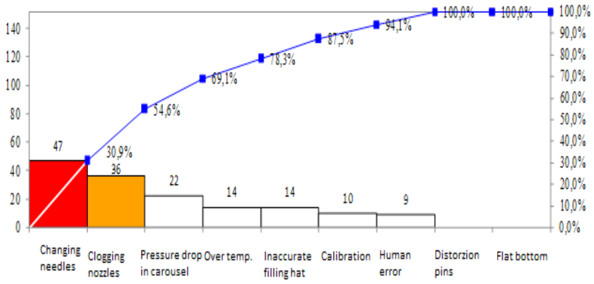

**Figure 6. Pareto for first group of samples 0.5 L**

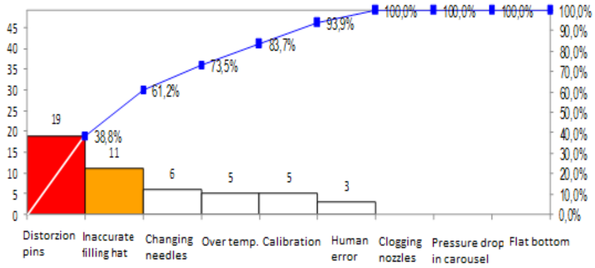

**Figure 7. Pareto for second group of samples 1.0 L**

At deviation of volume in this group was influenced by: flat bottom in the bottle (67 bottles), changing needles (27 bottles), distortion pins (27 bottles), calibration (10 bottles), inaccurate filling hat controlling (9 bottles), over temperature (8 bottles), pressure drop in the carousel (7 bottles), human error (7 bottles), and clogging nozzles on vacuum needles (0 bottle).

The main cause of defects is the so-called bottle with flat bottom, or as previously explained, the overheating of the generator which heats the bottles during their inflation, with a proportion of 41.4% (based on the total amount of problems). Together with the above defect from changing needles, pins and calibration distortions this comprise 80.9% of the problems in the process tested.

Group four 1.5 L: This group is dislpayed in the Figure 9 (samples filled in bottles of 1.5 liters). IV group was the group with the largest number of deviations in the volume of the finished product, and with the highest percentage of defects by as much as 41.8%. There were reported 267 defects.

All deviations of volume in this group were influenced by: changing needles (123 bottles), distortion pins (44 bottles), flat bottom in the bottle (37 bottles), pressure drop in the carousel (21 bottles), calibration (20 bottles), human error (15 bottles), incorrect hat regulatory filling (7 bottles), clogging nozzles with needles and vacuum (0 bottle), and over temperature drinks (0 bottle).

The main cause of deviation in this group are changing needles (before and at the time of manufacture), leading to inadequate length of the needles resulting in the defects in the volume of the finished product. Share this causes a high 46.1%, and along with defects caused by: distortion of needles, flat bottom with a bottle, pressure drop in the carousel, makes 84.3% of the problems. All these reasons have led to large variations in the volume of finished products and adversely affected the ability of the process which is why this group of samples and had the worst results.

### *3.1.2 Owerall deffects*

At the end of the determination of the causes for deviations in the beverages filling system in these 4 groups of samples, in the Figure 10 is shown it the overall result for total defects.

The percentage share of the individual causes of defects per group is different. As can be seen from Table 1 these causes appear with varying degrees of intensity.

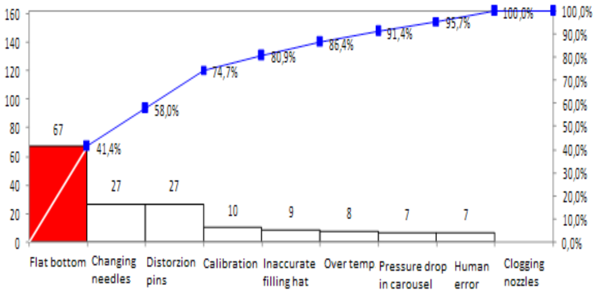

**Figure 8. Pareto for third group of samples 1.25 L**

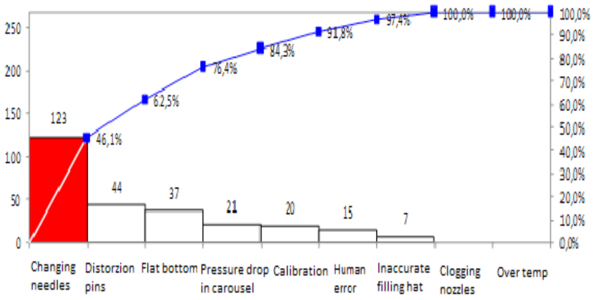

**Figure 9. Pareto for fourth group of samples 1.5 L**

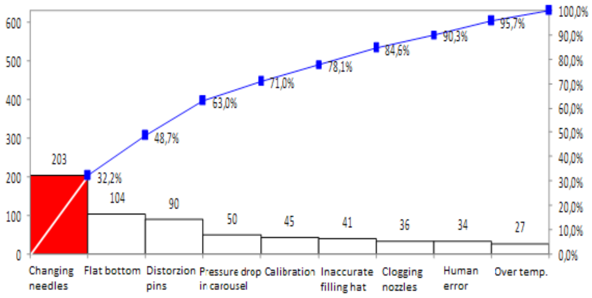

**Figure 10. Pareto for all groups of samples - total effects**

**Table 1. The percentage share of the causes of defects**

| **Bottle defects causes** | **I group** | | **II group** | | **III group** | | **IV group** | | **Total** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Nº** | **%** | **Nº** | **%** | **Nº** | **%** | **Nº** | **%** | **Nº** | **%** |
| Changing needles | 47 | 30.93 | 6 | 12.24 | 27 | 16.67 | 123 | 46.07 | 203 | **32.22** |
| Flat bottom | 0 | 0.00 | 0 | 0.00 | 67 | 41.35 | 37 | 13.86 | 104 | **16.51** |
| Distortion needles | 0 | 0.00 | 19 | 38.78 | 27 | 16.67 | 44 | 16.48 | 90 | **14.29** |
| Pressure drop | 22 | 14.47 | 0 | 0.00 | 7 | 4.32 | 21 | 7.87 | 50 | **7.94** |
| Calibration | 10 | 6.58 | 5 | 10.20 | 10 | 6.17 | 20 | 7.48 | 45 | **7.14** |
| Incorrect hat | 14 | 9.21 | 11 | 22.45 | 9 | 5.56 | 7 | 2.62 | 41 | 6.51 |
| Clogging nozzles | 36 | 23.68 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 36 | 5.71 |
| Human mistake | 9 | 5.92 | 3 | 6.13 | 7 | 4.32 | 15 | 5.62 | 34 | 5.39 |
| Over temperature | 14 | 9.21 | 5 | 10.20 | 8 | 4.94 | 0 | 0.00 | 27 | 4.29 |
| **Total** | 152 | 100.0 | 49 | 100.0 | 162 | 100.0 | 267 | 100.0 | 630 | 100.0 |

### 3.2 Discussion

It is necessary to sort out the process of filling beverages in bottles of 1.5 liters, which is located very close to the critical limits specifications or to tolerance prescribed by the legislation, or more precisely mean deviation in milliliters (-21.87 mL) and in percentage (1.46%).

From obtained results it can be seen that the tested process, although they meet the above legislation, there are large deviations in the volume of finished product. These results are initiated by the weak value of the indicator process capability.

According to tested processes in this paper, defects are classified into the following categories:
- charging process for Orangina 0.5 L - belongs to the group of imprecise and inaccurate process, (C = 0.80 and Cpk = 0.58),
- charging process for Limone 1.0 L - is a precision and inaccurate process, (C = 1.70 and Cpk 0.59);
- charging process for Orangina 1.25 L - is a precision and inaccurate process, (C = 1.93 and Cpk = 0.57);
- charging process for Orangina 1.5 L - is a precision and inaccurate process (Cp = 2.63 and Cpk = 0.07).

When comparing results of test processes, we can conclude that the procesess of filling in II, III and V group samples (1.0 L, 1.25 L and 1.5 L) are with acceptable precision index values (scatter) Cp, or that there is small discrepanies of the measured values. In contrast to the above three groups of samples, I group (0.5 L) has the weakest results.

## 4. Conclussions

Based on the results of the research can be drawn the following conclusions.

- The results of the measurement volume for all four groups of samples indicate that the values obtained, and the mean deviation from the nominal quantity in milliliters and percentage meet the conditions prescribed by the Law on refreshing soft drinks and similar products [1].

- Procesess of filling for II, III and V group of the samples (1.0 L, 1.25 L and 1.5 L) are with acceptable precision index values (scatter) Cp, while I group (0.5 L) in contrast to these three groups of samples, has the lowest index value potential (precision) and the process of filling for this group was assessed as imprecise.

- Index abilities (setting, accuracy) Cpk is unacceptable for all four tested groups of samples, or for all four tested processes. A process of fillingfora group of samples with 1.5 L, has the lowest value of Cpk (0.07).

- Results in all four groups tested process show that the center displacement processes is the lead one, and that values tend to lower the specifications. The biggest unajustement is shown for the charging process of the 1.5 liter, while the process of charging 0.5 liters has the most appropriate value of the alignment process.

- The study showed that IV group of samples have worst indicators for process capability and, in this regard, in this group occurs the greatest number of defects (41.8%), and the largest number of values beyond the borders of specifications, while a other groupa of samples have lowest number of defects (4.4%).

- Determining the cause deviation in the examined processes by applying the Pareto methods highlighted the fact that four groups of causes (needles soaking juice, heating with blowers bottle, the pressure in the carousel and calibration) cause the greatest number of defects (78.1%).

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