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IMPLEMENTATION OF CONTROL CARDS AND SUPPORTING METHOD IN PRODUCTION ENGINEERING

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Abstract:
In the article there were presented chosen method associated with statistical control of production processes. Mainly focused on control cards and Pareto-Lorenz analysis. Showed method were implemented to analysis production process stability of hearing aids in X company (the brand name don't give because date of production is secret). Researches were made few months after new assembly lines starts-up. Main aim of researches was defects types identification occurred in production process and determine the scale of effect. Finally received results were satisfactory, i.e. despite of occurred errors, control cards analysis showed that production process of BTE-type (Behind-The-Ear) hearing aids was stable.

Key words: *production engineering, statistical process control, Pareto-Lorenz analysis*

INTRODUCTION

In a situation when customer's requirements, technical and technological capabilities of manufacturers change, competition of meeting expectations of customer's needs increases. Manufacturers design and develop newer, more interesting and more efficient products and technologies. They outdistance each other. The situation is more serious when we talk about medical production which improves the quality of patients' life and even sometimes allows their functioning in society. There is no place for making mistakes and producing incorrect products. Process during which goods are manufactured subjects to total control. All of this is to eliminate internal errors which may be the cause of product's defect.

These issues fully refer to production engineering which subject is not only designing products and processes but also controlling, exploitation, organization and management of production processes.

This article aims to present simple tools that allow you to monitor the stability of the production process.

The object of the analysis was the production process of a BTE hearing aids in the company X. The analysis was conducted between June and July 2009 using the p control chart and Pareto chart. It aimed to show the level of defect in analyzed production processes.

SELECTED STATISTICAL TOOLS

To control production process we use different kind of tools like control charts, Pareto chart, histograms, flowchart, Ishikawa diagram, correlation diagram and many others. Statistical Process Control is the current (that is implemented in real-time process) process control which is used to detect the possible deregulations and consequently to improve quality of process [5, 8].

Control charts are used mainly to stability evaluation of the process, but also thanks to them we can find out when a process needs improvement and in what circumstances it should be left unchanged. Depending on the type of production and quality management system we use different kind of control charts. Appropriate for alternative evaluation and others for numerical evaluation. The first one we use for qualitative characteristics. They help us to make the division into good and bad elements, define the number of defects, deficiencies or damages of consignment. Other cards used for numerical control may be used only for measurable characteristic.

The statistical methods used in the company X are an essential and reliable tool of receiving control, necessary to provide the quality of technological processes [1].

Statistical Process Control is very important not only in receiving, but also in evaluating the product.

In company X were used cards for alternative evaluation which allow to control the process with various parameters. The purpose of this card is to reduce variation in the most optimal way. The deregulation appears when the upper limit of control is exceeded, assuming that the defect is less than 10%.

One of the main tasks of control charts is quick signal about any deviations. Card p (p - the fraction of defective items) is used for current control. To use this card it is necessary to take a random samples of n-element.

On the graph on the x-axis mark the numbers of samples and on the y-axis the fraction of defective items in the i -th sample. While plotting the control charts you consider two cases:

1. When we know the defectiveness of process.
2. When we don't know the defectiveness of process.

In the first case control limits are defined as follows [4]:

$$UCL = p + 3\sqrt{\frac{p(1-p)}{n}} \qquad P(Z>UCL) = 0.0013 \qquad (1)$$

$$LC = p \qquad (2)$$

$$LCL = p - 3\sqrt{\frac{p(1-p)}{n}} \qquad P(Z<LCL)=0.0013 \qquad (3)$$

When the industrial process is statistically stable, the probability of exceeding the upper or lower control line is close to 0.001. This occurrence can be considered as "almost impossible". However, you can specify top and bottom line for a given level of α [4].

$$UCL(\alpha) = p + u_{\alpha}\sqrt{\frac{p(1-p)}{n}} \qquad P(Z>UCL(\alpha))=\alpha \qquad (4)$$

$$LCL(\alpha) = p - u_{\alpha}\sqrt{\frac{p(1-p)}{n}} \qquad P(Z<LCL(\alpha))=\alpha \qquad (5)$$

If the defectiveness of process is not known, we calculate it as follows:

$$\overline{p} = \frac{\sum_{i=1}^{m} \hat{p}_i}{m} \qquad (6)$$

where:

$$\hat{p}_i = \frac{z_i}{n} \qquad i=1,2,...,m. \qquad (7)$$

z_i - the numbers of defective units in the i-th sample,
n - the number of elements in a single sample,
m - the number of samples with the same number of elements,
p - defectiveness of process.

Upper, central and lower lines have the following form:

$$UCL = \overline{p} + 3\sqrt{\frac{\overline{p}(1-\overline{p})}{n}} \qquad P(Z>UCL) = 0.0013 \qquad (8)$$

$$CL = \overline{p} \qquad (9)$$

$$LCL = \overline{p} - 3\sqrt{\frac{\overline{p}(1-\overline{p})}{n}} \qquad P(Z<LCL)=0.0013 \qquad (10)$$

The process is statistically regulated when the location of points on the control chart entwines the central line. To plot the p control chart first you have to calculate the defectiveness of each sample by the size of batch. On the OX-axis we mark the consecutive numbers of samples and on the OY-axis the corresponding defects. We write the results in the table.

We use this chart when the appearance of the deficiencies is not rare (eg. If the expected percent of defects is bigger than 5% of the total number of manufactured units).

The advantage of control charts while alternative evaluation is a rapid integration of various aspects of the quality of the examined product. Like this you can easily classify products which meet or don't meet the standards, basing on different quality criteria. Control charts appropriate for alternative evaluation don't need precise but expensive measuring apparatus and also time-consuming measuring procedures.

Pareto chart is a tool that shows which factors had the most significant influence on the chosen quantity. It shows that a relatively small number of factors affects a significant number of existing incompatibilities. This tool focuses on the most serious issues and is based on a rule:" 20% of causes determines 80% of errors". This tool illustrates the contribution of each factor in descending order and presents them as the cumulative sum (Lorenzo chart) [2].

Most of the people who examine the problems in company which they know very well, they know intuitively which factor is the most important. When there are several causes of the problem and one of them has the most important and dominant influence on the incompatibility, using the tool has no sense. However in case of complex causes such as searching the place where the defects form, time of occurrence or significance of the defects, Pareto diagram allows you to find the true cause of the problem.

IDENTIFICATION OF PRODUCT AND PROCESS

BTE hearing aid (Behind-The-Ear) so-called "hook" is placed behind the earlobe, fig. 1. It is characterized by high mechanical resistance. Its all the main parts are combined in one casing, which is placed behind the ear. This hearing aid is easy in daily using. It adjusts the volume automatically to a specific acoustic situation.

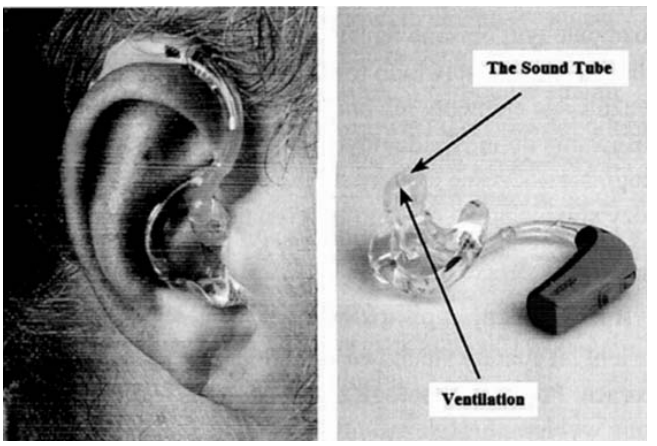

Fig. 1. Behind-the-ear hearing aids: on the Picture on the left placed in the ear, right – on the table. Are visible all external parts of heating aids, including individual earmold

A hearing aid consists of the following elements:

a. Input- usually microphone which takes noises.
b. An electronic amplifier that amplifies, and in some way transforms the signal from the microphone.
c. Output- small handset which sends changed signal into the ear canal.
d. Battery- provides the energy which hearing aid needs for working.

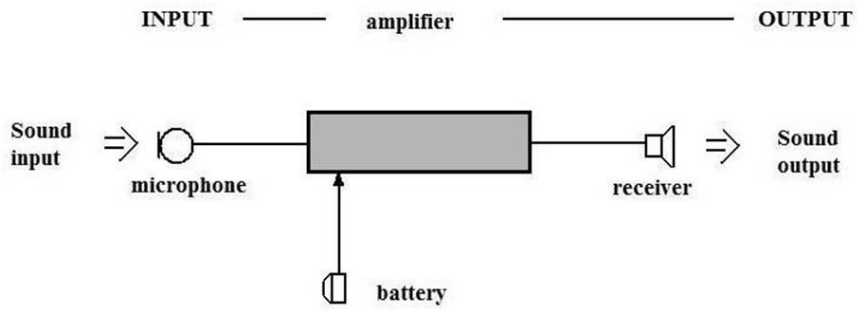

Fig. 2. Basic parts of hearing aid

The fundamental task of microphone is to collect sounds of surroundings and to send appropriate electrical signal to the amplifier of hearing aid. Mostly, the microphone collects the sounds from all directions, but it can also collect them from one direction (suppressing at the same time sounds coming from the side and back). It means that sounds coming from the front are more preferred and at the same time sounds coming from other directions are not amplified that much. Hearing aid user will have the impression that the signals coming from the side and back are suppressed. Therefore user will also have impression that this suppressed signals disturb the speech signal coming from the front not so much. Directional microphone consists of two independent identical microphones or a pair of identical microphones placed in one casing.

A hearing aid may also be equipped with a telecoil, which receives the sounds from the induction loop placed for example in cinemas, theaters, churches. The sound of the movie projector or system of the microphones is converted via the induction loop in a magnetic field which is received by telecoil in hearing aid. Most BTE have a switch that gives the user choice to listen through the microphone or the coil.

Another element of hearing aid is amplifier. Currently, most electronic amplifiers used in hearing aids are based on digital technology, which displaces analog technology. The main task of the amplifier is of course to strengthen the sounds to be heard by a hearing-impaired person. Amplified sound also has to be adapted to other individual characteristic of the damaged auditory organ- to the dynamics of hearing, to make all important sounds to be heard and at the same time not uncomfortably loud. This condition must be fulfilled for all frequencies – from low to high tones.

Hearing aids can have several programs – this means that hearing aid has a few different amplifier adjusted to different acoustic conditions. Hearing aid beside volume knob sometimes has also switch to change programs that user of hearing aid can choose one of few programmed settings. At the output of the hearing aid is a small receiver that transfers amplified and processed sound to the ear canal.

In BTE the sound is transmitted from the handset first to the horn of hearing aid- a hard, curved tube, made of plastic, which is an integral part of hearing aid. Then is transmitted through the soft tube, sound tubing to sound channel of earmold, fig. 1. From the handset to the ear canal signal needs to travel around 70 mm.

The task of battery is to provide electricity to make the hearing aid work. It is placed in a special box that you can open with your fingernail.

Stages of BTE hearing aid manufacturing process:

1. Preparation of errand.
2. Preparation of the lower casing;
3. The first person in CMFI- preparation the piece to solder the amplifier.
4. The second person in CMFI- points of soldering and solder terminals.
5. The third person in CMFI- closing the microphones in casing.
6. Closing the piece.
7. Testing the sound.
8. Acoustic control.
9. Range test.
10. Coating.
11. The first person preparing the amplifier- preparation of microphones and amplifiers.
12. The second person preparing the amplifier- resoldering.
13. The third person preparing the amplifier- putting the points of soldering.
14. Shield.

Hearing aid – BTE model is characterized by high mechanical resistance. Its all the main parts are combined in one casing, which is placed behind the ear. This hearing aid is easy in daily using. It adjusts the volume automatically to a specific acoustic situation.

EXAMINATION THE STABILITY OF THE HEARING AID PRODUCTION PROCESS

Production of BTE especially in the first months was unstable. Production of the model type Y started in April 2009. Many errors occurred in this assembly line. Employees responsible for product Y were looking for new solutions to minimize occurring errors. Used control chart type p was showing how many and which type of errors occurred during the day in this assembly line.

Interpretation of control charts for alternative evaluation is different than interpretation of control charts for numeric attributes. Exceeding the upper control limit informs us about the growth of defectiveness of the process, however exceeding the lower tolerance limit doesn't indicate the instability of the process but informs about reduction of defectiveness.

Control chart type p from the twenty-third week, fig. 3, shows us that in the beginning of the week many errors occurred, which gave a warning signal, and the upper tolerance limit was slightly exceeded. It could be caused by a staff turnover.

Figure 4 shows a typical graph where all the points are between the control limits. Points on the graph entwine control line, there is no signals informing about instability.

Week 25 (Fig. 5) also doesn't show anything wrong. For every process is normal to be variable and it's not possible to elimination. There are two groups of variability: random variation and special variability.

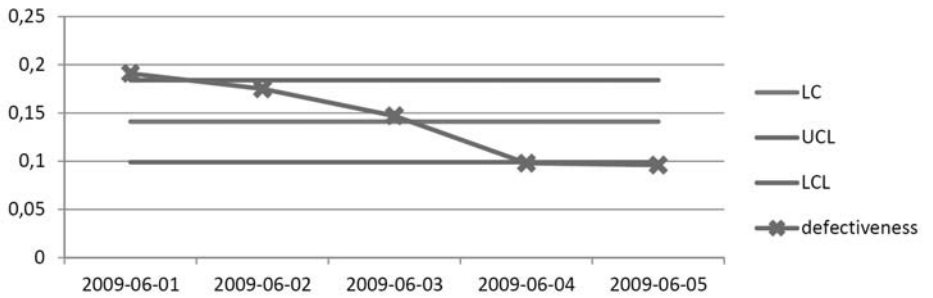

Fig. 3. Control cards p – production errors – hearing aids BTE – week 23 year 2009

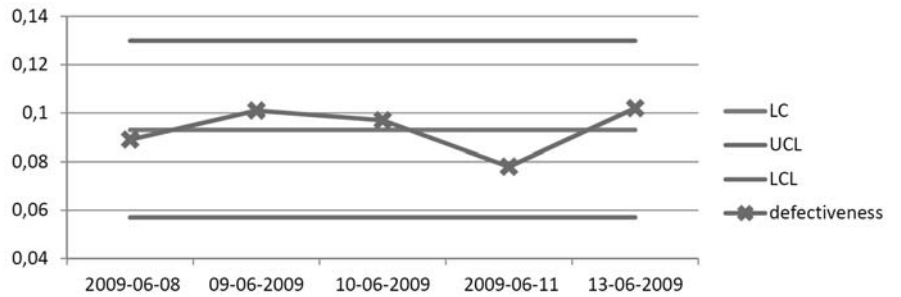

Fig. 4. Control cards p – production errors – hearing aids BTE – week 24 year 2009

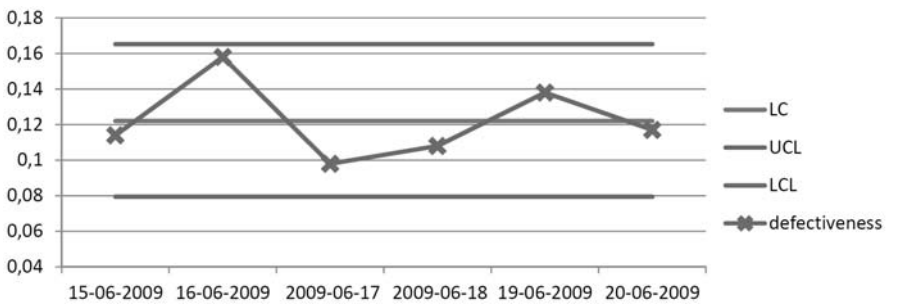

Fig. 5. Control cards p – production errors – hearing aids BTE – week 25 year 2009

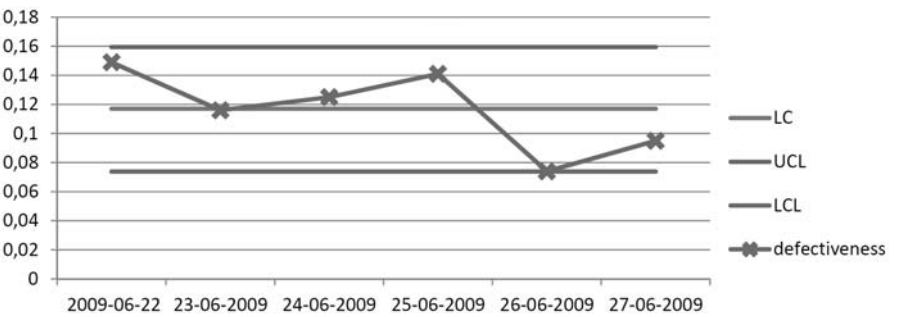

Fig. 6. Control cards p – production errors – hearing aids BTE – week 26 year 2009

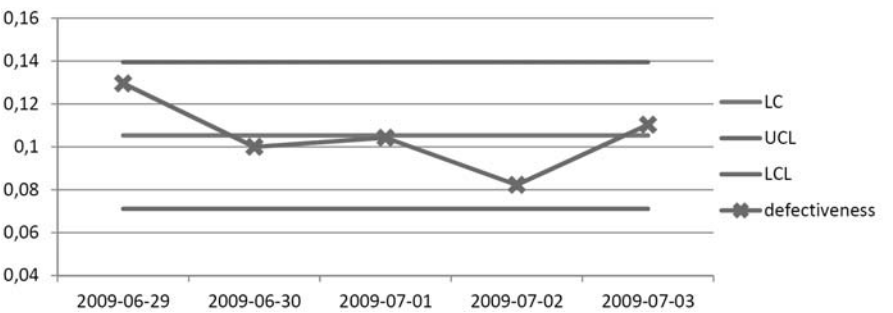

Fig. 7. Control cards p – production errors – hearing aids BTE – week 27 year 2009

Control chart from the twenty-third week shows the random variation. Random disruptions are developed accidental and of natural causes.

On the next control chart, fig. 6, the defectiveness is controlled. Points are situated between the limit lines.

Points on the control chart from the week 27, fig. 7, are situated closer to the average level than to the control limits. The lines connecting the individual points on the graph intersect the central line. This means that the process is stable.

Analyzed industrial process is regulated. Control chart from week 28 also showed no tendency to deregulation, fig. 8.

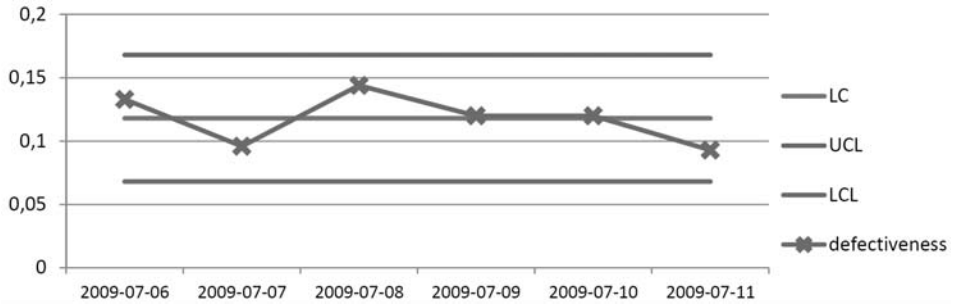

Fig. 8. Control cards p – production errors – hearing aids BTE – week 28 year 2009

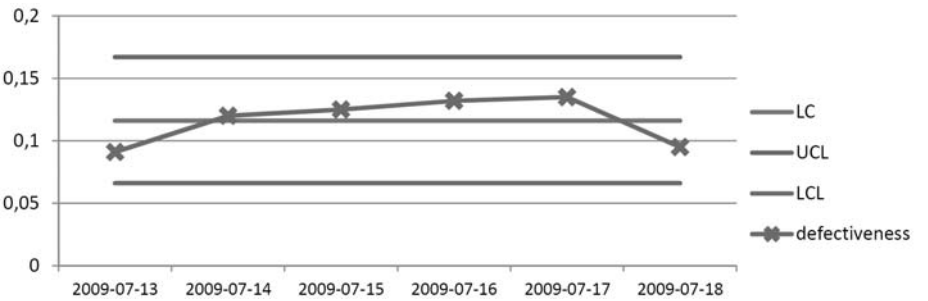

Fig. 9. Control cards p – production errors – hearing aids BTE – week 29 year 2009

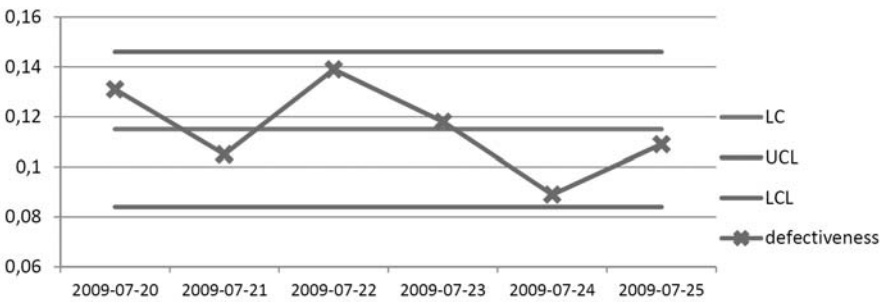

Fig. 10. Control cards p – production errors – hearing aids BTE – week 30 year 2009

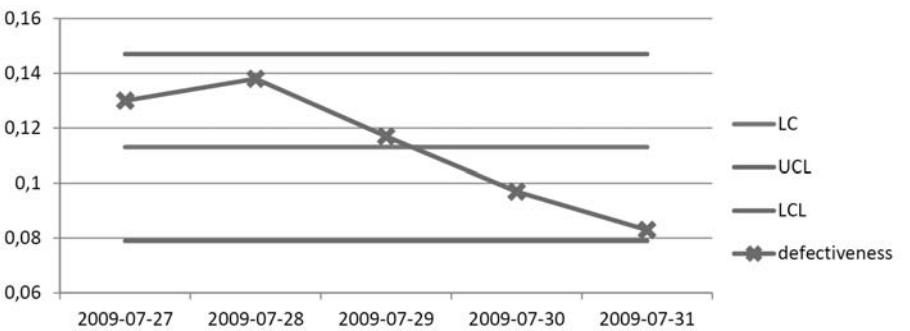

Fig. 11. Control cards p – production errors – hearing aids BTE – week 31 year 2009

This means that with the process is nothing wrong. Every day it's checked by many specialized engineers.

On the control chart from week 29, fig. 9, we can see some trend, following values show an upward trend. It could be caused by the consumption of a machine or process conditions.

The signals on control chart, fig. 10, intersect the control line. It means that the process is regulated. Occurred disturbances are random disturbances.

Fig. 10. Control cards p – production errors – hearing aids BTE – week 30 year 2009

On the control chart from week 31, fig. 11, we can see downward trend. This means that the defectiveness is reduced and the quality of BTE hearing aid is improved.

During the analysis also used Pareto diagram, fig. 12 and fig. 13. This diagram shows the three most important defects in the production [9]. It demonstrates that 80% of all errors occurred during the production are errors such as: VAE- overfill/no refilling on the cover of apparatus, FCC- no signal after switching on, FAA- distortion, audible sound should be typical for human speech. In June and July result was similar. Data for the analysis is presented in the table 1 and table 2.

Based on Pareto analysis we are able to make decisions, at which point in the process should we make changes to improve it to minimize the errors to the optimum level [3].

Table 1
Data to Pareto diagram of BTE hearing aid for June 2009

Defects	Number of defects	Defects part relative to the sum	Cumulative number of defects	Part the cumulative number of defects relative to the sum
VAE	493	30.736%	493	30.736%
FCC	172	10.723%	665	41.459%
F23	167	10.411%	832	51.870%
FAA	126	7.855%	958	59.726%
F24	106	6.608%	1064	66.334%
FHA	97	6.047%	1161	72.382%
F25	60	3.741%	1221	76.122%
FAE	39	2.431%	1260	78.554%
FCD	38	2.369%	1298	80.923%
F09	42	2.618%	1340	83.541%
F26	40	2.494%	1380	86.035%
F08	32	1.995%	1412	88.030%
F04	31	1.933%	1443	89.963%
F22	31	1.933%	1474	91.895%
F34	25	1.559%	1499	93.454%
F18	24	1.496%	1523	94.950%
FCB	21	1.309%	1544	96.259%
F15	12	0.748%	1556	97.007%
F16	10	0.623%	1566	97.631%
F17	10	0.623%	1576	98.254%
F21	6	0.374%	1582	98.628%
F19	5	0.312%	1587	98.940%
FAC	5	0.312%	1592	99.252%
F06	3	0.187%	1595	99.439%
F11	2	0.125%	1597	99.564%
FAB	2	0.125%	1599	99.688%
FJA	2	0.125%	1601	99.813%
VAC	1	0.062%	1602	99.875%
VGB	1	0.062%	1603	99.938%
VJA	1	0.062%	1604	100.000%

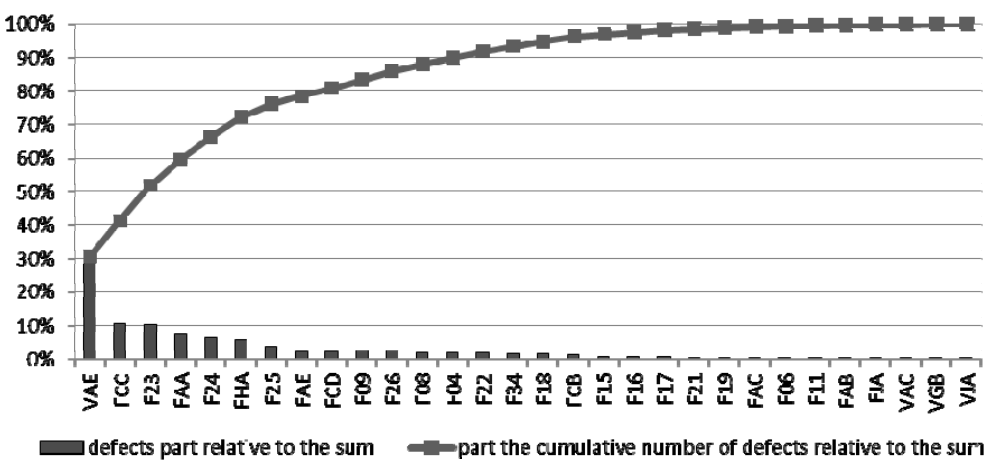

Fig. 12. Diagram Pareto -hearing aids BTE June 2009

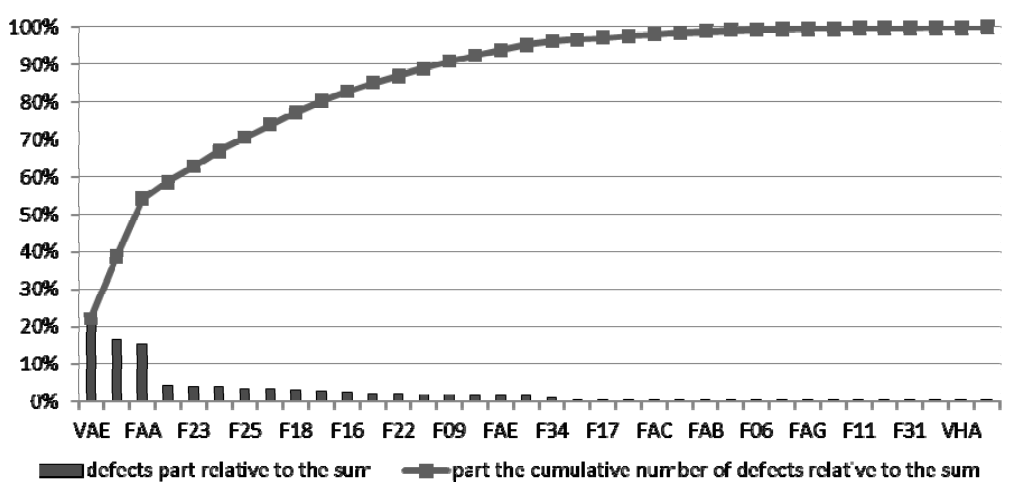

Fig. 13. Diagram Pareto -hearing aids BTE July 2009

Table 2
Data to Pareto diagram of BTE hearing aid for July 2009

Defects	Number of defects	Defects part relative to the sum	Cumulative number of defects	Part the cumulative number of defects relative to the sum
VAE	414	22.175%	414	22.175%
FCC	311	16.658%	725	38.832%
FAA	287	15.372%	1012	54.205%
F24	82	4.392%	1094	58.597%
F23	79	4.231%	1173	62.828%
FHA	78	4.178%	1251	67.006%
F25	67	3.589%	1318	70.595%
F04	64	3.428%	1382	74.022%
F18	62	3.321%	1444	77.343%
FCD	56	2.999%	1500	80.343%
F16	48	2.571%	1548	82.914%
F26	41	2.196%	1589	85.110%
F22	37	1.982%	1626	87.092%
F08	36	1.928%	1662	89.020%
F09	34	1.821%	1696	90.841%
F15	30	1.607%	1726	92.448%
FAE	28	1.500%	1754	93.948%
FCB	27	1.446%	1781	95.394%
F34	17	0.911%	1798	96.304%
F07	9	0.482%	1807	96.786%
F17	8	0.428%	1815	97.215%
F19	8	0.428%	1823	97.643%
FAC	8	0.428%	1831	98.072%
FJA	8	0.428%	1839	98.500%
FAB	7	0.375%	1846	98.875%
F21	6	0.321%	1852	99.197%
F06	3	0.161%	1855	99.357%
FJA	3	0.161%	1858	99.518%
FAG	2	0.107%	1860	99.625%
F05	1	0.054%	1861	99.679%
F11	1	0.054%	1862	99.732%
F29	1	0.054%	1863	99.786%
F31	1	0.054%	1864	99.839%
VCA	1	0.054%	1865	99.893%
VHA	1	0.054%	1866	99.946%
VJA	1	0.054%	1867	100.000%

CONCLUSION

SPC tools allow you to control the statistical stability of the process. The analysis of hearing aid production process in company X shows that this process is statistically stable. The points on the control charts doesn't exceed the tolerance limits. Production of BTE hearing aid in the test time was a production, which generated the largest number of defects. In company X employees are aware of the quality of produced products. The company cares about the products and about its customers, so they can enjoy the products without manufacturing defects.

Many specialized and experienced workers take care about every process. Thanks to them production is maintained at a high, international level. In addition, they bring the methods and tools into action that improve the process, provide new information about this process, effect on its stability and efficiency. Employees do their job honestly. It's very hard to find such a good employees who know their duties and who are aware of the responsibility they bear for every step in the company.

One of the most important statements in the case of statistical process control, is the ability to make decisions based on facts, not intuition. As the name suggests, SPC is a continuous collecting and analyzing numerical data and regulation which is based on taking the appropriate actions. For this purpose you need the appropriate reference standards and the process to be controlled must be predictable.

The process is statistically regulated when variability of the process arises from natural causes and it is called random variability. The process in which occurred special interference we call statistically irregular, unstable. This kind of process is unpredictable.

Using the SPC we should trend to eliminate "special variations" to make this process predictable, so we can control it statistically.

Currently, customer requirements have become so vast that attitude to quality problems changed. We trend to improvement by minimizing the size of dispersion and centralization the target values.

The analysis showed that the biggest amount of error in the production of a BTE hearing aids are errors such as:

- VAE- overfill/ no refilling on the cover of apparatus,
- FCC- no signal after switching on,
- FAA- distortion, audible sound should be typical for human speech

Quality engineer on this assembly line could improve the process by bringing the measures minimizing this errors into action. Control charts prevent the problems because they simplify detection of errors and changes in the process. This allowed for rapid identification of errors and the consequences for the entire manufacturing process. It should be noticed that the SPC measures not single but average values which present the current state of manufactured components in the most accurately way. The errors are signaled not at the time when they are caused by a small, random disturbances but at the time when they can have a significant for the whole process negative character.

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