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METHOD OF STATISTICAL CONTROL OF A PRODUCTION PROCESS

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ABSTRACT

This study presents a statistic control method for the manufacturing process. This control applies on the most diverse industrial areas such as production lines, data traffic, medical system, the evolution of social media or economic system and is one of the main tool used in the control and management of quality. We based this work on the use of the equipment of measuring horizontal projector type of profiles, StarrrettOptical, from the laboratory equipment. We can imagine an algorithm of measuring for the item "washer" and on the algorithm base, we create a measuring program of this item. Moreover, in this paper, we present on to detail the programming mode of the QuadraCheck 200 system which equip the horizontal projector for profile StarrettOptical. On the base of the data set got through a lot of measures of 14 items got through broaching on the broaching machine DPM 08 84, from the laboratory equipment, we analysed broaching process capabilities and we calculate data capability of this process and of this machine.

KEYWORDS: data capability, broaching, statistical control.

1. INTRODUCTION

The statistic control of the processes is intended for monitoring the sequential processes for verification of their stability and quality.

The most important part of the evolution of this control took place in the last 10-20 years, when new methods and new applications were developed, that replace the traditional methods of statistical control.

In the consumer society that has developed in modern times, people are surrounded by many products, with a utility and multiple importance. The statistic control of the processes tries to answer the question: "How can control or insurance the quality of the products?" [1].

Quality is a concept with many aspects. First of all, it is a dynamic concept in the sense that it is constantly changing over time. For example, a computer which 10 years past was a top product, nowadays can be worthless. On the other side, the quality of the product and processes that we use reflects the quality of life. Moreover, the product quality definition is highly dependent on the area in which this quality is appreciated. For example, products considered to be at a medium quality in developed countries, are regarded as excellent products in developing countries. But also the characteristics that define a product in terms of quality are subject to an evolution in time. A few years ago American cars were equipped with extremely powerful engines and consumption that by our standards seems huge. Nowadays, more and more consumers are shifting towards economic cars, with lower consumption, even with electric engines or hybrid. The public transport management systems have the role of increasing the efficiency of public transport services and the capacity to satisfy user demands. These include systems informatics for the distribution of information regarding the timetable of public transport, prices, routes, systems for automatic collection of the cost of travel, systems for locating vehicles. These measures lead to public transport services improvement so the transport will be more comfortable, more accessible, in safety conditions, quick and economic.

The production process must be monitored and evaluated. Any issue must be investigated, and the production process improved so that the issue eliminated.

The quality of the final products determines the quality of the production process. There cannot exist a high-quality production process which leads to getting low-quality products.

Some features of final products can be measured, so can be numerically expressed. These quality features are named variables. The other feature cannot be measured, but only appreciated from a quality point of view. For example, a receptacle can be watertight or not. In the speciality literature, the binary type characteristics of quality that can be qualitatively appreciated, are called attributes.

In the technical terminology, the names of continuous numeric variables, discrete numeric variables and category type variables are also used [2]. Traditionally, attributes are only binary and can have only two values:” compliant” or “non-compliant”.

2. OBTAINING THE MEASUREMENT SET OF THE DATA BY USING THE HORIZONTAL PROJECTOR OF STARRETTOPTICAL PROFILES

The StarrettOptical horizontal profile projector is equipped with the QC 200 control system, which allows to select and display the measured elements with its help, Fig. 1. The QC-200 control system allows the recognition of 3 types of geometric elements: point; line and circle (circle arc). Between these elements, the system can determine relationships like angle or distance. The point, line and circle are called features, and the angle and distance are called relationships.

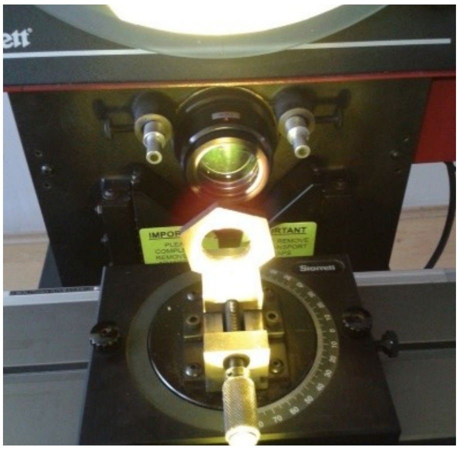

Fig. 1. *Attach the part to the measuring device*

The programmable softkeys command specific functions for the measurement operations Depending on your current activity, the options activated by the softkeys are displayed at the LCD bottom. Reference system 1 is the permanent reference system and the reference system 2 is the temporary reference system. Reference system 2 is useful for performing incremental measurements. The reference system number used is displayed on the first row of the screen, close to the units of measurement. The polar/cartesian key is used to choose the polar coordinates or cartesian coordinates.

Selection using markings on the graded scale: the symbol appears in the top right corner of the display screen. For a point selection, set the intersection of the graduated scale marks to the desired point and then press the Enter key. If you want to use the optical detector to select the point, press the softkey corresponding to the Probes option.

The selection of the required point number to recognise an entity it's done by pressing the key which brings the angles to 0° at the beginning. The required number of points is displayed on the left side of the screen.

Establishing the measurement program

The measurement program aims to determine the dimensions of the inner contour of the ”Washer” landmark, obtained by broaching on the DPM 08 84 broaching machine.

The execution drawing of the reference is shown in Fig. 2.

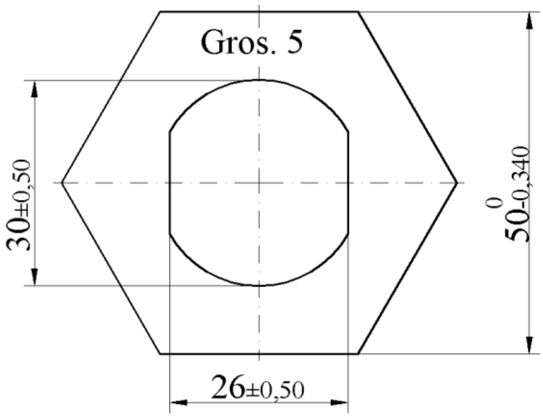

Fig. 2. *Washer drawing [3]*

The diameter measurement of the cylindrical bore (d_1) and the determination of the distance between the rectilinear areas of the inner contour (d_2) must be carried out using the reference measuring program.

This will determine the diameter of the bore by measuring 7 points and determine the origin of the reference system in the centre of this bore. Then, one of the rectilinear areas is measured, determining 5 points on this area and choosing the new alignment corresponding to the given rectilinear line. The other rectilinear area is also determined, and the distance between the two lines is constructed. For each of the measured and constructed elements, the tolerance limits corresponding to the class mK for free dimensions are set (SR ISO 2768).

Programming the QC 200 system

The programming capacity of the QC 200 system allows the automation of repetitive inspection cycles. The programs are user-recorded inspection sequences and stored in the system memory. Using the programs saves time by reducing the number of keys pressed.

Using a program ensures that the steps of the measurement algorithm are strictly followed, which improves the accuracy of the measurement and its confidence level. The program can include any measurement or function on the system panel.

The programming function behaves like a recording tape. To record, we must press the *RECORD* key. After that, the program will record any pressed key.

We should analyse the benchmark to identify the measurements and to determine the points required by each entity.

We must choose the order of measurement such that we can use the *AutoRepeat* and *MeasureMagic* functions. These two functions are special functions of the measurement program.

The *AutoRepeat* function allows you to resume the measurement of a selected entity type until it exits this loop.

The *MeasureMagic* function allows the automatic recognition of the entity type after determining a certain number of points on this entity.

The difference between a small program and a large program is only the number of steps. The large program is not particularly complicated than the small one.

After that, an operator can run the program, at any time, to simplify the automation and inspection process.

If the screen is set to the graphic mode when a program run, it will show the point that you must to choose for the measurement.

The indication mode, graphically shows the required entity and displays an arrow showing the next point required by the program. A registered program can be edited to add or remove steps. Before registering the program is recommended to be planned the measurement algorithm.

The properties of the program will be:

- *UsemachineRef: Yes* — the reference system of the machine is used;

- *Clearfeatures: Yes* — the alignments, reference systems and entities established above are deleted;

- *Use as recorded: No* — the entities will be established during the measurement;

- *Pausetolresults: Iffail* — if the measured size is not within the tolerance range, the program stops running;

- *Print tolresults: Always* — the measured value is printed regardless of the measurement result.

The system settings corresponding to this program will be:

- *Targetingview: On* — the graphical representation of the measured entity is displayed;

- *Select datum: 1* — the reference system number 1 is used (the machine can carry out measurements in two reference systems, both established by the user);

- *Probe: Auto* — the selection of the measured points is done using the optical sensor;

- *Units: mm* — the units of measure are millimetres;

- *Mode: Cartesian* — the reference system is Cartesian;

Will mount the washer in the latch type device of the profile projector, and as the measuring base, it will choose the bore, Fig 3.

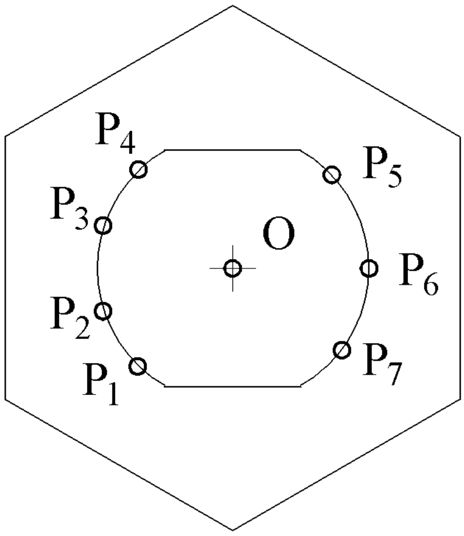

Fig. 3. *Establishing the origin [3]*

The machine is reset to zero to both the X and Y axes.

The tolerance limits of the diameter are set:
As = 0,20 mm and Ai = 0,20 mm.

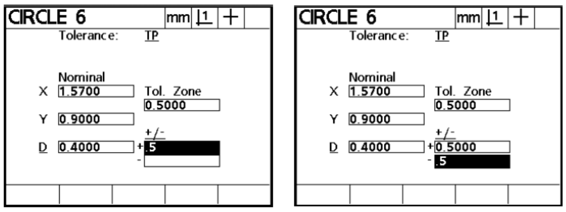

Fig. 4 *Establishing the allowable tolerances for the diameter of a circle [3]*

After the respective diameter is checked, the test result is displayed in a specific way. If the size it matches within the tolerance limits, a check mark appears next to the tolerance and the value is shown in black.

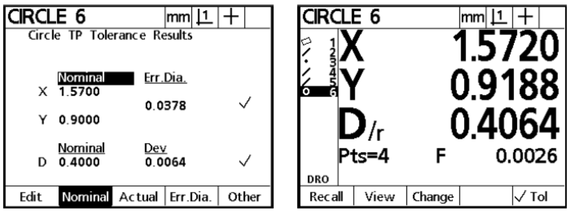

Fig. 5 *Diameter in the tolerance field [3]*

If the diameter is outside the tolerance range, next to the value appears the × sign in a circle and it displays the value in light-coloured characters.

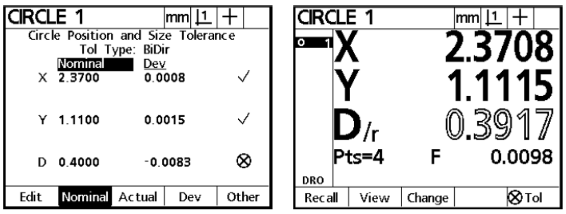

Fig. 6. *Diameter outside the tolerance field [3]*

A new alignment is made (SKEW) by determining five points on one of the rectilinear areas. By selecting five points on the other rectilinear area, a line is determined. On the basis of the two elements previously determined, we construct the distance.

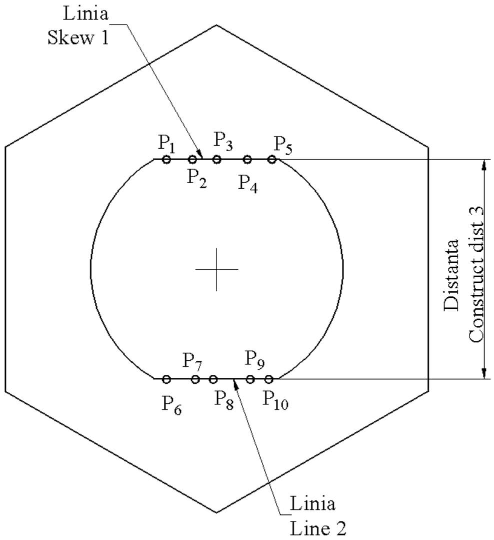

Fig. 7. *Establishing a new alignment and building distance*

To set the tolerance limits, select the built distance and press the Tol key; it establishes the nominal value of the dimension and the tolerance limits, Figure 8.

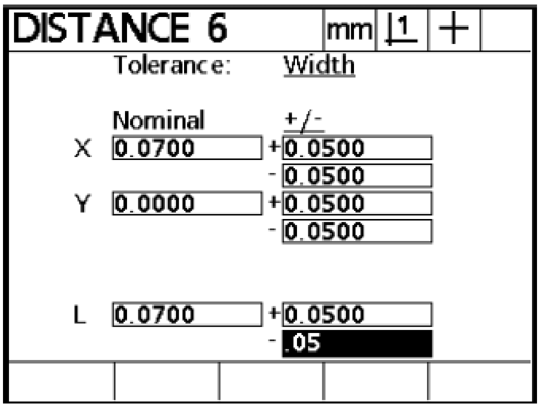

Fig. 8 *Establishing allowable tolerances [3]*

Analysis of the capacity of the process of obtaining the washer reference

In the case of the mentioned process, it measured 14 samples of one piece, samples for which the diameter of the cylindrical area, the distance between the rectilinear zones and the deviation from the symmetry of these areas, was measured. The statistical control was applied to the quality characteristic "distance between rectilinear areas" [2]. The data for the distance discussed are represented in Table 1.

Table 1. *Dimensions measured for distance*

Sample	x1	$\bar{X}$	R
1	25,989	25,989	0,113
2	25,980		
3	25,967		
4	25,976		
5	25,997		
6	26,000		
7	26,019		
8	25,961		
9	25,994		
10	26,057		
11	25,944		
12	26,033		
13	25,962		
14	25,970		

The string of measured values is ordered in ascending order.

The limit values are: X_{min} = 25,944 mm and X_{max} = 26,057 mm.

- The amplitude of the string is:

$$R = X_{max} - X_{min} \quad (1)$$

R = 0,113 mm.

- The number of intervals in which the value string is divided is calculated:

$$k = 1 + 3{,}322 \cdot lg\, n \quad (2)$$

where n represents the total number of values, in our case 14. It is obtained k = 4,8 ≈ 5 intervals.

- The amplitude of the intervals is determined by the relation:

$$a = R / k \quad (3)$$

It is obtained: a = 0,023.

The frequencies of the values corresponding to each interval are obtained, Table 2.

Table 2. *The frequencies of each interval*

From	Up to	Number of values	Probability
25,900	25,944	1	0,07
25,944	25,967	3	0,21
25,967	25,989	4	0,29
25,989	26,012	3	0,21
26,012	26,034	2	0,14
26,034	26,057	1	0,07

The histogram of frequencies and the distribution function of the probabilities of obtaining the respective dimension are represented in Fig. 8 [4], [5].

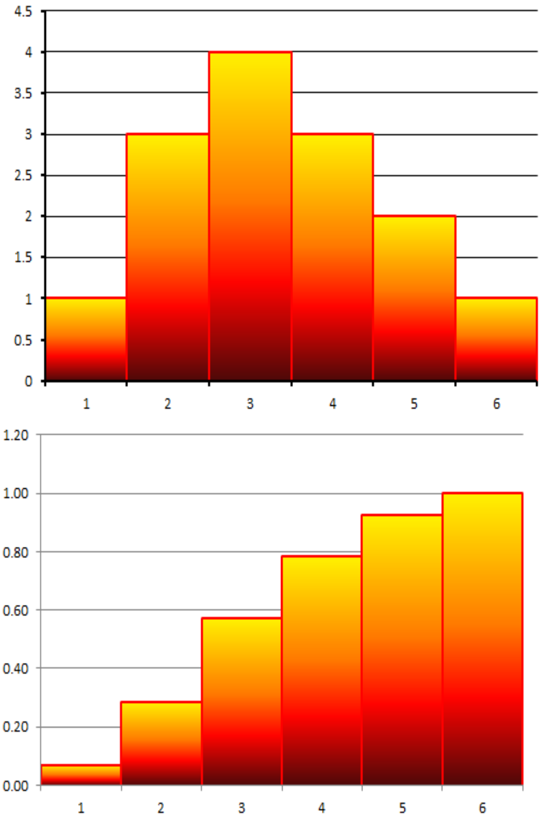

Fig. 8 *Histogram of frequencies and distribution function*

Elaboration of diagrams R and $\bar{X}$

Since in this case, we have to deal with individual observations, the method of tracing the R and $\bar{X}$ diagrams must be adapted to this case. In the specialized literature, [1] it is recommended to use the grouping of observations in this way being artificially created lots with a number of copies m > 1. In the considered case, we have 14 observations that we will group two by two. So we will get 14-2+1=13 groups, presented in Table 3.

Table 3. *Grouping of the data set*

Nr. crt.	X_1	X_2	X_{med}	R
1	25,989	25,980	25,985	0,009
2	25,980	25,967	25,974	0,013
3	25,967	25,976	25,972	0,009
4	25,976	25,997	25,987	0,021
5	25,997	26,000	25,999	0,003
6	26,000	26,019	26,010	0,019
7	26,019	25,961	25,990	0,058
8	25,961	25,994	25,978	0,033
9	25,994	26,057	26,026	0,063
10	26,057	25,944	26,001	0,113
11	25,944	26,033	25,989	0,089
12	26,033	25,962	25,998	0,071
13	25,962	25,970	25,966	0,008

Next, we calculate the average of the amplitudes, with the formula:

$$\bar{R} = \frac{\sum_{i=1}^{n-m+1} R_i}{n-m+1} \tag{4}$$

For the row of values given in Table 3, we obtain the value $\bar{R} = 0{,}039$ mm.

- Control limits for $\bar{X}$ will be:

$$U = \bar{X} + \frac{Z_{1-\alpha/2}}{d_1(m)}\bar{R};\quad C = \bar{X};\quad L = \bar{X} - \frac{Z_{1-\alpha/2}}{d_1(m)}\bar{R}. \tag{5}$$

We obtain the values: U = 26,093 mm; C = 25,990 mm and L = 25,886 mm.

- Control limits for R are calculated with the relations:

$$U = \bar{R} + \frac{Z_{1-\alpha/2}\cdot d_2(m)}{d_1(m)}\bar{R};\quad C = \bar{R};\quad L = \bar{R} - \frac{Z_{1-\alpha/2}\cdot d_2(m)}{d_1(m)}\bar{R}. \tag{6}$$

We obtain the values: U = 0,127 mm; C = 0,039 mm and L = -0,049 mm. Since the amplitude cannot be negative, we will choose L = 0 mm. The respective diagrams are shown in figures 9 and 10.

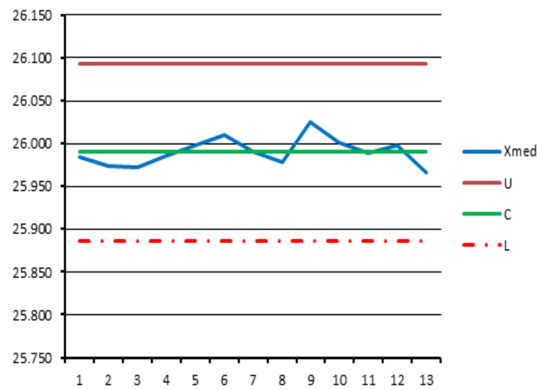

Fig. 9. *Diagram $\bar{X}$*

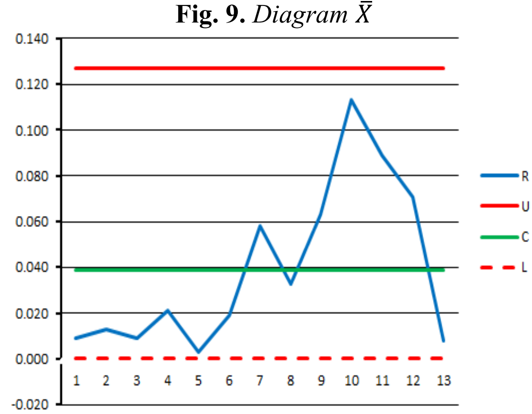

Fig. 10. *Diagram R*

3. RESULTS AND CONCLUSIONS

Determining the process capacity index:

$$C_p = \frac{U - L}{6\sigma} \tag{7}$$

where U and L represents the allowable deviations required by the technical specifications, respectively U = +0,20 mm and L = -0,20 mm. For σ = 0,030 we obtain the value: C_p = 2,22.

If we want to study the position of the scattering field in relation to the tolerance limits, we use the index C_{mk}. That describes the value of the scattering field corrected with the position of the average value:

$$C_{pk} = min\left(C_{ps}, C_{pi}\right) \tag{8}$$

where,

$$C_{ps} = \frac{\overline{X} - LSL}{3\sigma};\ C_{pi} = \frac{USL - \overline{X}}{3\sigma} \tag{9}$$

Another capability index, which describes the machine tool capability, is the "machine capability index", noted: C_m.

The capacity index of the machine is calculated by the formula:

$$C_m = \frac{USL - LSL}{6\sigma} \tag{10}$$

We obtain the index C_m = 2,22.

As in the previous case, if we want to study the position of the scattering field in relation to the tolerance limits, we use the index C_{mk}. That describes the value of the scattering field corrected with the position of the average value:

$$C_{mk} = min\left(C_{ms}, C_{mi}\right) \tag{11}$$

where,

$$C_{ms} = \frac{LSL - \overline{X}}{3\sigma};\ C_{mi} = \frac{USL - \overline{X}}{3\sigma} \tag{12}$$

We obtain the values C_{ps} = 2,22; C_{pi} = 2,22; C_{pk} = 2,22.

Interpretation of process capability indices

For the value obtained: C_{pk} = 2,22 the index C_{pk}>2 so the trust level is high and there is a high chance that the non-compliant products will be detected using the control diagrams [6].

Thus, it can be concluded that:

- since on the previous performances, we can determine the capacity of the process;
- It requires previous performances to perform the functions to get a series of quantifiable results that meet the established requirements;
- we carry the study of the capacity of a production process with the main purpose to determine the capacity to get compliant products;
- to perform a process capability analysis, it is necessary to have a data set corresponding to a process considered stable;
- in order for the data to reflect the stability of the process, they must have been collected after the process has been properly adjusted;
- the distribution of the data must correspond to the distribution of the population for all the obtained products as long as the process is stable;
- the observations must be obtained based on a random scheme and the data set must be representative.

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