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# THE MAGNITUDE OF THE CENTERED IN COMPONENTS: EVALUATION

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**ABSTRACT**: Nowadays the industry is in a commercial and technological competition, then is needed adjust the mensuration systems and obtain technologies that allow achieving satisfactory results to the systems of quality´s control. This paper has as a main objective to provide the necessary information to evaluate the magnitude of the centered in pieces of high technological responsibility.
**Keywords**: Mechanical elements, quality control, six sigma

## INTRODUCTION

The necessity of the quality control processes compatibility and updating with the guides and the standards demands from the whole process a continuous improvement and a constant preparation of the staff related with the metrological confirmation. (7)
In Cuba, to assure the pieces interchangeability, there is the¨NC16-30 “Fits and Tolerances”, which is concordant with the ISO 286/1 and ISO 286/2, used at international level. This norm is one of the tools used in the mechanical engineering to guarantee the interchangeability of the mechanical elements.
When the manufactory of a part is required, the production of mechanical elements needs the specifications. So that the piece can enter in service, it should complete certain characteristics. The obtained product is accepted when it is in a margin of tolerances, what means that this it won’t have an exact measure to the one predicted.
The manufactured part should be among maximum and minimum dimensions, since it is considered impossible the absolute precision from the technical point of view. It is for this reason that bigger or smaller values of dimensions are tolerated to the nominal.
The intervals are the purpose of tolerance is admitting a margin for the imperfections during the manufacturing of the piece. From the economic point of view, it is good to specify the biggest value possible of tolerance, while the piece maintains its functionality, since while minor is the margin of tolerance, will be the most cost of the piece also the piece will be manufacture with more difficult.
The tolerance (T) is not more than the grade of inaccuracy allowed in the obtaining of a certain dimension. It can also be defined as the difference between the maximum measure and the minimum measure:

$$T = Dmáx\text{-}Dmín \qquad \text{(Equation 1)}$$

The tolerance is the interval of values in that it should be this magnitude. It determines the acceptance or rejection of the manufactured components.

To achieve the interchangeability it is necessary to be based exactly on the tolerance, classifying them for each work class, in order to be able to assign in each case the one that corresponds, according to the operation conditions or the purpose of the work.

In order to facilitate the interchangeability of pieces, the countries have established charts of tolerances. With this purpose, Systems of Limits and Adjustments have been established. Their application became international with the application of the norms ISO. (8)(16)(17)

We face the problem of evaluating the magnitude of the one centered in pieces of high technological responsibility, for what we intend to provide the foundation and theoretical elements that offer the information of this evaluation.

## 2. DOMAIN FACTORY PROCESSES. PROCESS CAPABILITY AND PHILOSOPHY SIX SIGMA

### 2.1. Process capability

Objective: To reach stable and capable processes, and later on to control the system.

At the present time the evaluation of the processes is carried out fundamentally by means of the calls "abilities" or the corresponding indexes of capacity. These are the computation´s results, certain dispersion indexes that are comparted, the central process´ tendency and the specification tolerance. The determination and interpretation of the indexes of capacity is used for: (15)

- To recognize the laws of the behavior of a process.
- As indicator that the process, machine or the complex system, are able to provide the yield required inside the tolerance.
- To provide, by means of comparison, the possibilities to evaluate the process.

The parameters are distinguished in the following way:

- Potential of the process
- Capacity of the process

To designate the capacity of the process, the variable $c_p$, $p_p$, $c_m$ are used. These have the following meanings:

- $c_p$ = capacity of the process (process capability)
- $p_p$ = preliminary capacity of the process (preliminary process capability) commonly used by the signatures Ford and GM
- $c_m$ = capacity of the machine (machine capability)

The capacity of the process indicates the potential possibilities to obtain a quality´s characteristic inside specification limits. This parameter doesn't consider the localization of the process. For this reason, a centered normal distribution will be used, even if this is not presented. A normal distribution is characterized by two parameters:

- the arithmetic stocking μ
- the standard deviation σ

In a normal distribution, the interval understood among $\mu\pm1\sigma$ contains around 70% of the population's values, the interval $\mu\pm2\sigma$, with double range, it contains near 95% of the values, and the interval $\mu\pm4\sigma$, 99,99% of the values. In the area with $\mu\pm3\sigma$ (range of the interval = 6σ), it is 99,7% of the population's values. The index $c_p$, is calculated: (2)

$$C_p = \frac{T}{6\sigma} = \frac{LS - LI}{6\sigma} \qquad \text{(Equation 2)}$$

where: T = Tolerance; σ = Standard deviation of the normal distribution of Gauss; LS = superior Limit; LI = inferior Limit

The recommended practical value of the potential of the process, for normal conditions, for a value ≥ 1,33. In the capacity of the process the following abbreviations are used: $c_{pk}$, $p_{pk}$ and $c_{mk}$. Which have the following meaning: $c_{pk}$ = critical capacity of the process (critical process capability); $p_{pk}$ = critical preliminary capacity of the process (critical preliminary process capability); $c_{mk}$ = critical capacity of the machine (critical machine capability)

The process capability is an indicator of the quality to check the long term stability in the frequent repetitions. In this parameter is considered the localization of the process. The clients want long term a certain critical capacity of the process $c_{pk}$. This will be completed by the respective suppliers. The capacity of a process means that the preset limits are completed. This capacity should be guaranteed during a long period.

$$C_{pk} = mín.\{C_{po}; C_{pu}\} = C_p - \frac{|d_{med} - \mu|}{3\sigma} \qquad \text{(Equation 3)}$$

where:

$$C_{po} = \frac{LS - \mu}{3\sigma} \qquad \text{(Equation 4)}$$

$$C_{pu} = \frac{\mu - LI}{3\sigma} \qquad \text{(Equation 5)}$$

where: $\mu$ = arithmetic stocking; $\sigma$ = Standard deviation of the normal distribution of Gauss; LS = superior limit; LI = inferior limit

Is the practical reference point for the capacity of the process in a general value ≥1,00. Therefore, the potential of the process is generally bigger that the capacity of the process.

$$C_{pk} \leq C_p \qquad \text{(Equation 6)}$$

where: $c_p$ = capacity of the process (process capability); $c_{pk}$ = critical capacity of the process (critical process capability)

When $c_{pk} = c_p$ means that the process is centered, the stocking the characteristics of the quality (localization in the process) it is exactly in the center of the tolerance. While smaller it is $c_{pk}$ in comparison with $c_p$, far away it will be the localization of the process' stocking with regard to the center of the tolerance.

The localization of the stocking of the process (their central tolerance) will be described by means of the consideration of both index $c_p$ and $c_{pk}$, for example: when according to the client's expectations they are required and the values are completed:

$$C_p \geq 1{,}33 \quad y \quad C_{pk} \geq 1{,}0 \qquad \text{(Equation 7)}$$

where: $c_p$ = capacity of the process (process capability); $c_{pk}$ = critical capacity of the process (critical process capability)

### 2.2. SIX SIGMA (6)

Objective: To achieve a process with the minimum errors are possible. The method Six Sigma is based on an analysis of the real processes where is looked for to identify the most important parameters, the possible errors and the process´ indicators. These will be directly influenced on the base of an objective and statistical analysis (to see the method (5)(12)(13)). The deviations or dispersions will be strictly limited and the errors or quality´s problems or any type will be eliminated.

The transparency and trazability in the analysis, the making of decisions and the certification of the project´ success, they are especially important in the method Six Sigma. Together with these they will combine so many techniques of the quality´s administration like methods of data analysis and the systematic training of the workers.

Six Sigma was developed by the middle of the years 80 of last century in United States for Motorola like a focus of the total quality (TQM = Total Quality Management). However, with the time step it has been introduced in the entire world in numerous companies. Although this method was initially designed for the production, in the last years it has strengthened and expanded more and more in the sector of the services. It is for this reason that it has been implemented in the area of the Logistics (for example, in the distribution) opportune and appropriately. Two main methods exist in the methodology of Six Sigma, one for the existent processes and another for the new ones:

- **DMAIC** (**d**efine, **m**easure, **a**nalyze, **i**mprove, **c**ontrol) it is used for the existent processes.
- **DMADV** (**d**efine, **m**easure, **a**nalyze, **d**esign, **v**erify) it is used for the new processes.

We can determine the level of Sigma, in agreement (conformity) with the quantity of errors in a process by means charts or statistical programs are used. The Chart 1 shows the levels of Sigma according to the number of defects in a million produced units (PPM = parts for million). Some companies hope their suppliers fulfill the quality Six Sigma in their production processes; this demonstrates that the manufactured products are of high quality. The Chart 2 shows the values for the case that the stocking has an allowed displacement of 1.5σ. Six expressed Sigma with this that the probability of finding an error in a million (PPM = parts for million) it is smaller than 0,002, and in a process with allowed displacement of the stocking of 1.5σ, the probability is increased to 3.4 errors in a million.

According to the available estimates, most of the processes in the industry that does not apply the method of Six Sigma are around 3σ and 4σ. A significant improvement can also be achieved near 5σ or more, by means of the traditional methods of processes improvement, only that with more difficulty.

**Table1.** Statistical Interpretation of 6σ for a centered process.

| Process centered | | | | | |
|---|---|---|---|---|---|
| $c_p$ | $c_{pk}$ | Sigma | Without errors (%) | Without errors /mill. | Errors / mill. |
| 0,33 | 0,33 | 1 | 68,2689480 | 682689,480 | 317 310,520 |
| 0,67 | 0,67 | 2 | 95,4499876 | 954499,876 | 45 500,124 |
| 1,00 | 1,00 | 3 | 99,7300066 | 997300,066 | 2 699,934 |
| 1,33 | 1,33 | 4 | 99,9936628 | 999936,628 | 63,372 |
| 1,67 | 1,67 | 5 | 99,9999426 | 999999,426 | 0,574 |
| 2,00 | 2,00 | 6 | 99,9999998 | 999999,998 | 0,002 |

**Table 2.** Statistical Interpretation of 6σ for a displacement of the stocking of 1,5σ.

| Displacement of the stocking of1,5σ | | | | | |
|---|---|---|---|---|---|
| $C_p$ | $C_{pk}$ | Sigma | Without errors (%) | Without errors/mill. | Errors / mill. |
| 0,33 | -0,17 | 1 | 30,2328 | 302327,9 | 697 672,1 |
| 0,67 | 0,17 | 2 | 69,1230 | 691229,8 | 308 770,2 |
| 1,00 | 0,50 | 3 | 93,3189 | 933189,4 | 66 810,6 |
| 1,33 | 0,83 | 4 | 99,3790 | 993790,3 | 6 209,7 |
| 1,67 | 1,17 | 5 | 99,9767 | 999767,3 | 232,7 |
| 2,00 | 1,50 | 6 | 99,9997 | 999996,6 | 3,4 |

It is considered a process centered in that case that the half diameter of specification coincides with the process central tendency. In the practice this ideal case is manifested with little frequency, nevertheless the correction of the process should spread the one centered of the same one, standing out that it stops processes with index of capacity $c_p>1$ a defined allowed range exists of having uncentered of the process. The use in the practice of centered processes guarantees a rational use of the specification tolerance in the factory processes. (3)

The centered coefficient (K) determines the position of the stocking in the process with regard to the half diameter of specification. When this coefficient is positive, it means that the curve is displaced to the left of the axis of the stocking (Figure1) when the coefficient is negative. It means that the curve is displaced toward the right of the axis of the stocking (Figura2). The coefficient of having centered you can determine for the following calculation:

$$K = d_{med} - \mu \qquad \text{( Equation 8)}$$

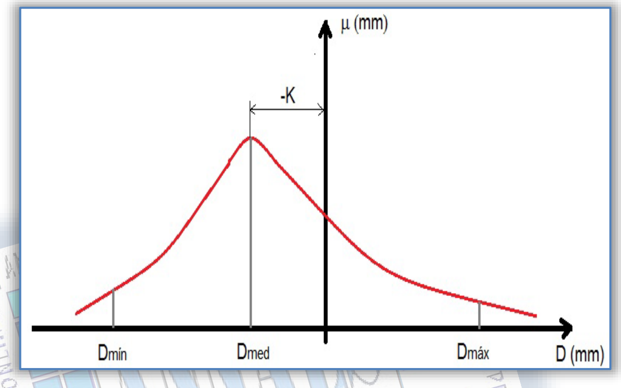


**Figure1**. Representation of K when the value is negative

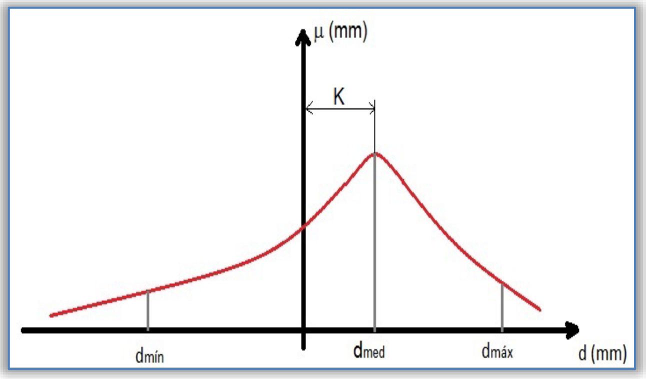


**Figure 2**. Representation of K when the value is positive

## 3. ECONOMIC ASPECTS

At the present time we are submerged in marked international economic crisis, which affects to the companies that in turn are in a ferocious competitiveness. Many of the companies have already drained the forms of increasing the profitability and the capacity investor; it is for this reason that they are come in the necessity from being restructured until the critical size. When the companies take out to the market their products they meet with similar goods and to inferior prices.

It becomes necessary to operate with a bigger productivity and a "more economic quality", keeping in mind that this doesn't mean that it is with an inferior quality. To equality of

manufactured units it is more productive that produces less faulty units, is for this reason that quality and productivity are intimately related.
From the economic point of view, the main importance of this investigation lies mainly in the little application that has in the industrial practice the behavior of the capacity's indexes of the process. Keeping in mind that the increase of the demands in the quality of the productions forces to carry out studies and to upgrade knowledge; to elaborate methodologies, procedures that can be applied technologically and that they are not extremely complicated.
It should be had very present that the current intempt of the mechanical industry to win markets is really difficult, mainly for the development that this has reached in the international environment and in this intempt it has vital importance the prestige that the productions are able to be won and the measure in that they satisfy the expectations of the consumers. For this purpose, it is indispensable an increase of the demands in the productions, what won't allow in the future to do without of the valuation of the indexes of capacity of the process $c_p$ and $c_{pk}$, to satisfy the expectations. (3)
All the above-mentioned is part of the way of the industry should continue to achieve something that is very important for the modern administration: the certification according to ISO 9000 norms, with the installation of a system of a quality´s management, with the corresponding certification of means and laboratories.

## 4. INFLUENCE INDEX $c_p$ AND $c_{pk}$ IN THE COSTS RELATED WITH THE QUALITY

It should be pointed out that this contribution, from the economic point of view, cannot be quantified in a general way in all their magnitude, but rather it is manifested in concrete data for each company, for each application and each shop, at least at the moment, but its importance is very evident if we want that the mechanical industry reaches the place that corresponds in Cuba and in the world. The objective, for the definition and calculation of the mensuration uncertainty, the valuation of their influence about the qualitative valuation of the process, as well as the limitations regarding the tolerance, they cannot be considered for separate, but rather it is necessary to consider them like economic technical conditions to optimize. In that case, it is necessary to consider and to compare the expenses that are had in diminishing the mensuration uncertainty in phases so early as the planning, the design and the elaboration of the technology, with the costs of waste, reprocess and the costs that it implies in the future due to the shipment of faulty products to the client.
The derived costs of the errors take place product of the inclusion of pieces that are not in correspondence with the specifications. It is those costs that appear from the company until the client, when a product doesn't complete the expectations. To this important category of the costs it is related a great loss of the company, since leads to the client's dissatisfaction, the loss of prestige of the product and the loss of opportunities of the company.
These costs include:

- Treatment of the reclamations.
- Costs for refund.
- Costs for responsibility on the product and payment of damages.
- Fine of contract.
- Gain losses.

In the mark of the quality management and the efficiency company´s improvement it is necessary to optimize the conformity costs and to minimize the non-conformity costs. Among non-conformity costs of components are:

- Costs of not planned control.
- Internal and external costs of the defects.
- Derived costs of the defects.

These defects are reflected in the productive process and specifically in the control of the quality like costs of short comings (what costs to make the things wrong) characteristic of the process, for not keeping in mind the mensuration's uncertainty.
Otherwise, if we work on the base of the mensuration's uncertainty, these costs they would become parts of the costs of prevention, which are generated with the objective of planning and to improve the quality management and the formation with a view to prevent and to avoid the appearance of shortcomings for not keeping in mind the mensuration's uncertainty. The appearance of shortcomings would be eradicated taking the relating outlined actions to not

working with the tolerance specified in the plane of the piece, but with the correction of this, taking into account the difference of the grade of bilateral uncertainty that corresponds in each case.

## CONCLUSIONS

- All mensuration process is characterized by a series of data, which have a quantity of information that can be obtained by means of its statistical prosecution and among those statistical parameters a fundamental importance has the parameters that describe the central tendency and those that describe the dispersion of the process that are expressed by the index $c_p$ and $c_{pk}$.
- To consider the localization of the process the coefficient is determined of having centered K.

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