ABOUT THE ASSESSMENT OF THE CAPABILITY OF MANUFACTURING PROCESSES

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INTRODUCTION

The product quality results from the manufacturing process. Besides a compelling technical documentation, a correct maintenance of the equipments, a good training of the personnel etc. it is necessary too an efficient control of the process in order to realize and maintain in time an adequate production regarding the quality.

1. THE TECHNOLOGICAL PROCESSES STABILITY

The variability of the quality characteristics in a technological process represents the result of the influences exerted by the arbitrary and systematic causes. The systematic causes act onto a certain direction producing specification deviations and having as effect an inappropriate production. The arbitrary causes are extremely numerous, hard to identify or measure and act onto any direction.

The technological process is stable if it is only on the influence of the arbitrary causes, the systematic causes effects being removed. If the influence of the systematic causes has not been removed the technological process is considered unstable. A process is statically stable if the characteristic's values are assigned under a known statistical repartition law. A process is dynamically stable if the characteristic's values present in time the same dispersion and the same grouping center, i.e. the process is maintaining the initial specific distribution.

The variation of characteristic due to the influences of the aleatory causes embodies the dispersion field D (Fig.1). If th process is stable and the distribution law is the normal one, the probability that the characteristic's values are between the limits LI and LS could be determined using the relation (1), where σ is the standard deviation of the characteristic's values and $\bar{x}$ their arithmetic mean.

$$P(LI \angle x \angle LS) = \frac{1}{\sigma\sqrt{2\pi}} \int_{LI}^{LS} e^{-\frac{(x-\bar{x})^2}{2\sigma^2}} dx \qquad (1)$$

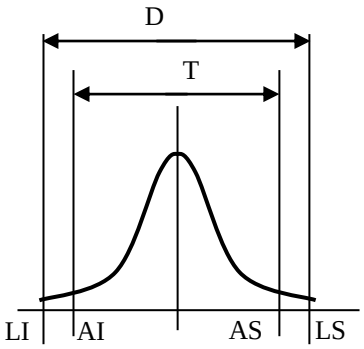

Figure1. The dispersion field and the tolerance field.

The tolerance field T represents the area where the characteristic may vary without affecting the product quality. The relationship between the size of dispersion field D and the size of tolerance field T has consequences on the manufactured products quality but also on the technological process economical efficiency. Predicting a smaller tolerance than the natural dispersion of the process will determine a significant number of improper products. Contrarily, if the tolerance is greater than the natural dispersion of the process, the manufacturing will be uneconomical because it means that very accurate machines are used under their capacity.

2. THE ASSESSMENT OF THE PROCESSES CAPABILITY

The process capability represents a dimension of the accuracy or uniformity wherewith the process accomplishes the product quality characteristics. The purpose of studying the capability is to get knowledge about the manufacturing process capacities and its real performances.

A usual statistical dimension of the capability is the dispersal interval of the characteristic. Thus, the capability dimension indicates the predictable interval of the variation which will be exceeded only with a small probability. A percent of 99.73% of the observed values are included into the ±3σ

(6σ) interval (Fig.2), 95% cover the ±2σ interval and 68% the ±σ domain.

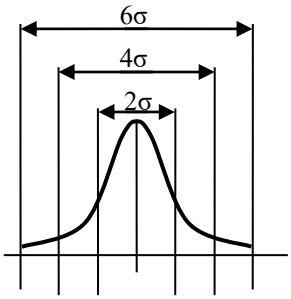

Figure 2. Intervals of dispersal.

The coefficient C (relation (1)) is used as sintetic indicator of the capability.

$$C = \frac{6\sigma}{T} \tag{1}$$

In relation (1) T represents the tolerance of the quality characteristic. The value of C coefficient is good if is set into the interval 0,6 – 0,8 [1], [2]. A bigger value for C signify an improper process regarding the working possibilities (Fig.3) and a smaller value means a process more accurate than needed, with

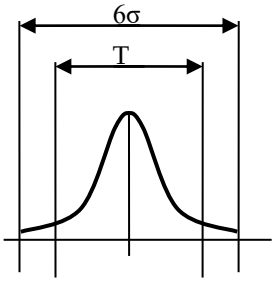

Figure 3. Improper process.

economical losses (Fig.4). In this situation only products having high accuracy requirements will be manufactured using the respective equipments.

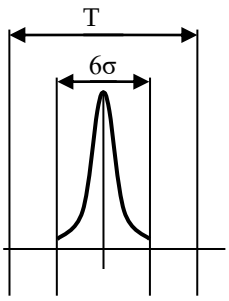

Figure 4. Over- accurate process.

In order to introduce the statistical control the size of dispersal interval must be determined, as a dimension of the capability. The modern production develops with high productivity so it is necessary that the sample used for the preliminary study of the statistical control to be representative.

Based on the process type and its characteristics two methods are used to determine the capability, i.e. the method of high volume inspection and the method of low volume inspection.

3. THE METHOD OF HIGH VOLUME INSPECTION

In this case, from the resultant production enough number of specimens is sampling, by manufacturing order and continually. The number of specimen in the sample is recommended between 100 and 300 pieces. For every piece the marked quality characteristic is measured and the results are plotted.

If the manufacturing process is only under the influence of aleatory causes, the characteristic's values has a single repartition, i.e. the instant repartition. To establish if the systematic cause's influences were removed (the process is stable) some methods can be used, as follows: the iterations method, the method of successive differences, the signs criterion, Wallis-Moore test etc.

The statistical repartition is obtained using the homogenous data. The data are ordered and related to their frequency of occurrence. To relieve the data tendency of grouping around a certain value grouping by classes is using. The size of *a* interval result from the Sturges' relation (2), where x_{max} , x_{min} represent the extreme values of the characteristic and n the number of observations.

$$a = \frac{x_{max} - x_{min}}{1 + 3{,}322 \log n} \tag{2}$$

Based on this values it's recommend to lay-out a sampling data sheet relieving the dispersion [3].

The statistical parameters of the experimental repartition result from relations (3) – (5), where $\bar{x}$ represents the arithmetic mean, *s* – the dispersion, *n* - the number of pieces on the sample, f_i - the absolute frequency and *c* – the centre of the interval (the value with higher frequency).

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i' f_i}{n} a + c \quad (3)$$

$$s^2 = a^2 \left[\frac{\sum_{i=1}^{n} x_i'^2 n_i - \frac{\left(\sum_{i=1}^{n} x_i' f_i \right)^2}{n}}{n-1} \right] \quad (4)$$

$$x_i' = \frac{x_i - c}{a} \quad (5)$$

The accordance testing between the experimental repartition and the theoretical one can be done using the following tests: χ^2 test, Kolmogorov test, Massey test. Also one recommends the distribution's normality checking with histograms or probability grid methods.

If the experimental values distribution is close with the normal distribution one can determines the probable damaged fraction *p* with the relation (6), where $\Phi(z)$ represents the Laplace function and z_s, z_i result from relations (7) – (8).

$$p = 1 - [\Phi(z_s) - \Phi(z_i)] \quad (6)$$

$$z_s = \frac{T_s - T_c}{\sigma} \quad (7)$$

$$z_i = \frac{T_c - T_i}{\sigma} \quad (8)$$

If *p* belongs to the interval 0,001 – 0,02 than the process is statistically controllable. The smaller values have the significance of a process extremely precise and values bigger than 0,02 indicate a improper process, uncontrollable.

4. METHOD OF LOW VOLUME INSPECTION

This method is recommended when the process has a high efficiency, doesn't allow big sampling or is difficult to determine the characteristic's values. According to the production rhythm and the technological process particularities some specimen will be sampled periodically, having each of them a number *n* of pieces. It's recommended that *n* to be between 4 and 10 for the measurable characteristics and 20 – 60 for the attributive ones, the specimen number being approximately 25.

For each specimen one will determine the following statistical parameters: the arithmetic mean, the amplitude and the standard deviation. These parameters will be used to estimate the parameters of the products batches resulted from the manufacturing process. Thus, it is necessary that the specimen parameters to represent the same theoretical parameter, i.e. to be homogenous.

Control of the homogeneity of the inspection dispersions is made using the χ^2 test. One will determine the (9) values for each specimen, where s_i^2 represents the specimen's i dispersion, l_i - number of freedom degrees and σ^2 is estimated with relation (10).

$$\chi_i^2 = \frac{s_i^2 l_i}{\sigma^2} \quad (9)$$

$$\sigma^2 = \frac{\sum_{i=1}^{n} s_i^2}{n} \quad (10)$$

The values resulted hereby will be compared to $\chi^2_{(\alpha,l_i)}$ for a certain significance level α. The specimens which do not comply with condition (11) are considered not being an estimation of the general dispersion and will be removed.

$$\chi_i^2 \prec \chi^2_{(\alpha,l_i)} \quad 11)$$

The Dixon test is used to verify the homogeneity of the inspection means. According to this test one calculates the mean for each specimen and than are ordering based on relation (12), where m_1, m_2, m_3 represent the smaller means and M_1, M_2, M_3 the bigger ones. Than, one determine the ratios r_{ij}, according to Table 1, and compare them with the theoretical values for significance level of 1%. If the calculated value is over the theoretical value than the specimen mean (the bigger or the smaller one) is fairly different and the respective specimen is removed.

$$m_1 \prec m_2 \prec m_3 \prec \ldots \prec M_3 \prec M_2 \prec M_1 \quad (12)$$

Even for the high volume inspection, for low volume one must establish the repartition law of the

controlled quality characteristic for all specimen founded homogenous regarding the dispersion

Table.1. Dixon test.

Ratio	The test for the smaller mean	The test for the bigger mean
r_{10}	$\frac{m_2 - m_1}{M_1 - m_1}$	$\frac{M_1 - M_2}{M_1 - m_1}$
r_{11}	$\frac{m_2 - m_1}{M_2 - m_1}$	$\frac{M_1 - M_2}{M_1 - m_2}$
r_{12}	$\frac{m_2 - m_1}{M_3 - m_1}$	$\frac{M_1 - M_2}{M_1 - m_3}$
r_{20}	$\frac{m_3 - m_1}{M_1 - m_1}$	$\frac{M_1 - M_3}{M_1 - m_1}$
r_{21}	$\frac{m_3 - m_1}{M_2 - m_1}$	$\frac{M_1 - M_3}{M_1 - m_2}$
r_{22}	$\frac{m_3 - m_1}{M_3 - m_1}$	$\frac{M_1 - M_3}{M_1 - m_3}$

and the mean. When the specimen includes 10-30 pieces the Massey test is recommended, based on the differences (13), where $F_n(x_i)$ represents the empirical repartition function, $\phi(z_i)$- the normal distribution and z_i is rated normal variable according to relation (14).

$$d = |F_n(x_i) - \phi(z_i)| \qquad (13)$$

$$z_i = \frac{x_i - \bar{x}}{s} \qquad (14)$$

The differences (13) are calculated for each specimen and than the (15) condition is controlled, where $d_{\max}$ represents the maximum value of the differences (13) and $d_{\alpha,n}$ - the limit value for a certain confidence level and a certain specimen volume.

$$d_{\max} \le d_{\alpha,n} \qquad 15)$$

The failed fraction will be established alike as for high volume inspection.

5. CONCLUSIONS

For mass and high class production the only alternative with economical efficiency to maintain the quality between the established limits is to apply the statistical control. Thus, it is necessary that the manufacturing process to be stable, i.e. statistically controllable. First step to apply the statistical control consist in establishing of the process capability.

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