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STUDY OF MACHINING ERRORS USING THE EMPIRICAL STATISTICAL METHOD

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Abstract**—**The paper presents a study of machining errors via empirical statistical method. A batch of 243 cylinder bearing roller parts was used, with the diameter as measured feature.

There are revised the main theoretical aspects concerning technical measurements and the study of machining errors using the empirical statistical method.

Three measuring methods and equipment are used: orthotest, analogical system and digital micrometer connected to a specialized statistic printer.

A few conclusions arise and a series of issues to be further achieved are revealed.

Keywords**—**technical control, machining errors, empirical statistical method.

I. INTRODUCTION

MACHINING errors have been a ceaselessly concern matter in elements machining process [1]. Modern manufacturing of complex surfaces supposes using numerical control machines [2] and coordinate measuring machines for dimensional inspections. These technologies also require sophisticated statistical methods in errors calculus [3], [4] and analysis models for efficient control for production process, [2], [5], especially in mass production. However, these cutting edge machining and control methods are extremely expensive and from economical, practical and educational perspective, an empirical statistical method proposed in the present paper can be used in errors estimation in various applications. The results achieved through the analysis of the data using the above mentioned method, to be developed in this paper, are a useful feed-back tool, as to the measures to be taken in order to improve the machining process.

II. GENERAL ASPECTS UPON TECHNICAL CONTROL

Due to objective and subjective conditions, the real values of measured parameters cannot be determined with absolute precision. The measurements are affected by measuring errors.

Random errors are errors that vary aleatory as value and sign. They cannot be set previously and cannot be eliminated. The mathematical statistics allows for finding the influence of random errors upon machining precision [6].

The selection of controlling methods and means is made considering metrological parameters (division value, measurement limits, measuring forces etc.) and economical indicators (instrument price, productivity, sustainability etc.). The metrological indicators prevail when the prescribed precision for parts to be machined impose this [7].

The control by sample is applied for series production or mass production, upon a fraction of production volume.

Ignoring the influence of systematic factors, a certain feature presents different random values, when machining and measuring the parts. These values will be between two limits, each value having its own frequency. The character of these values spread (with their frequencies) between the two limit values can be represented by a distribution law.

If the factors producing the dispersion of effective dimensions are random, by the same order, independent and in large number, then the law of repartition of effective dimensions is the normal distribution law (Gauss's law) [8].

III. STUDY OF MACHINING ERRORS BY EMPIRICAL STATISTICAL METHOD

The results of measurements upon a batch (sample) of parts can be statistical processed by empirical methods or by calculus [6].

The empirical statistical method consists in:

1) systematic measurement of $200 \div 500$ *parts made in the same conditions;*
2) processing and plotting the results;
3) comparing the data to the prescribed values in the drawing of the part or from the corresponding standards.

Based on the drawn conclusions, the appropriate actions can be taken and then machining process will be continued.

The frequency distribution and the empirical repartition can be graphically represented as histogram, frequency polygon or empirical distribution curve [6], [8].

IV. INSTRUMENTS AND EQUIPMENT

1) Finding the distribution curve for a batch of parts using the orthotest tool, Fig. 1 [9].

Using the orthotest instrument implies a series of disadvantages, such as:

a) low productivity (requires long time duration for processing and interpretation of measurements data);

b) errors introduced by the human factor during reading the values.

Fig. 1. Measurement using the othotest

2) Finding the distribution curve for the dimensions of a batch of parts using an analogical system, Fig. 2.

An analogical measuring system is envisaged in order to eliminate the above mentioned disadvantages.

Fig. 2. Analog measurement system

The proposed system consists of a transducer based on an differential inductive sensor, connected to a personal computer via an amplifier-adaptor, an analog-digital converter and a microcontroller. Specialized software is installed on the computer allowing for statistical data analysis [10].

The advantages provided by the system are:

a) allows for direct data recording on the computer for display, processing and storage;

b) high precision and high accuracy;

c) the opportunity of using the specialized software "Quick Statistica" owned by the "Tolerances, Measurements and Dimensional Control" Laboratory;

d) high productivity.

3) Finding the dimensions distribution curve for a batch of parts using the digital micrometer connected to the statistical printer, Fig. 3., [11], [12].

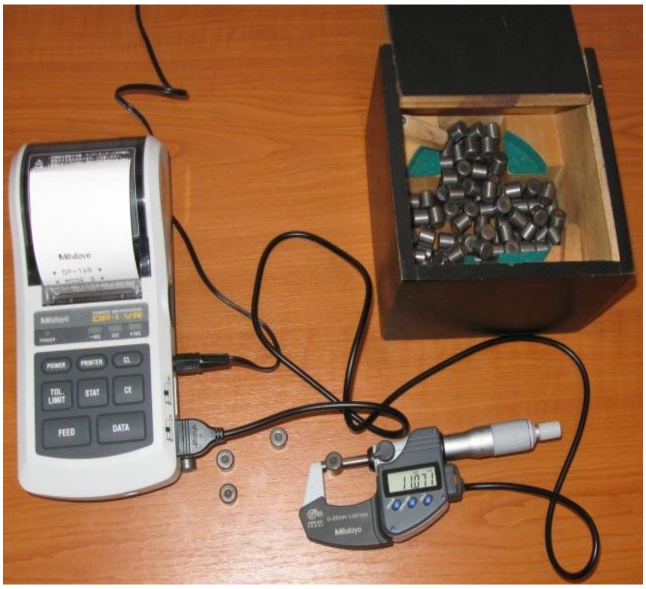

Fig. 3. Measurements using the digital micrometer connected to the statistical printer

The above described method may be the most suitable alternative, due to benefits concerning both accuracy and effectiveness.

V. EXPERIMENTAL RESULTS

Using the three proposed methods, the diameter of 243 roller parts was measured.

1) *orthotest,* Fig. 4.

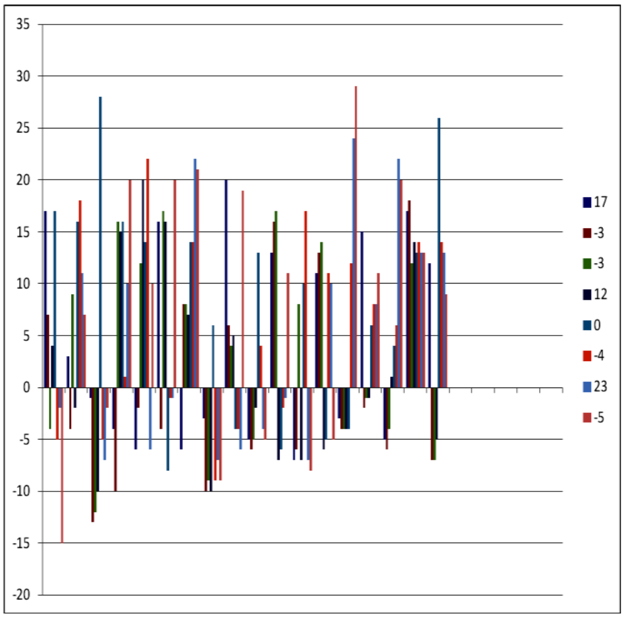

Fig. 4. Distribution of measured values

2) *analog system*, Fig. 5, 6.

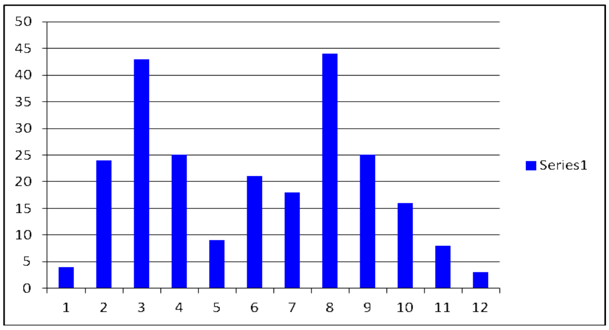

Fig. 5. Frequency distribution histogram

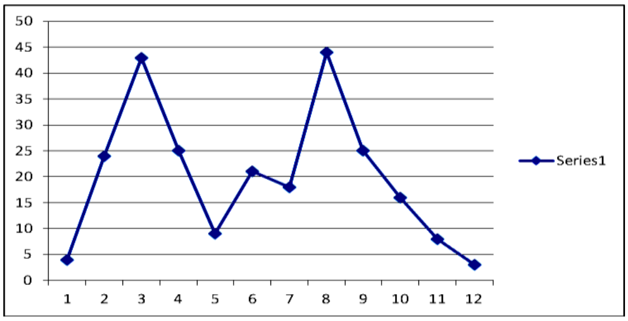

Fig. 6. Frequency polygon

3) *digital micrometer and statistical printer DP1 – VR*, Fig. 7-9.

From Fig. 9., it can be noticed that in order to be close to a Gaussian distribution, the plot needs to be completed with a "missing region" with a "reversed" Gaussian distribution. This is explained by the fact that the lacking parts were the suitable ones and the parts we measured are the rejected parts (smaller and greater and usually outside the prescribed tolerance limits). The discarded parts (scrap parts) distributions seem to be Gaussian, too.

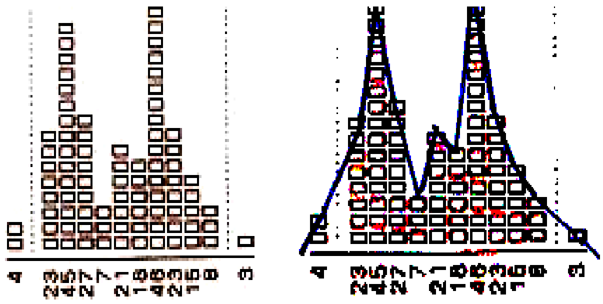

Fig. 7. Histogram and frequency polygon

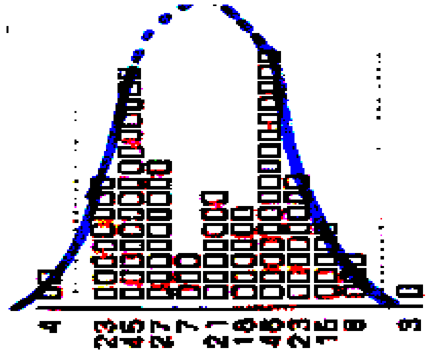

Fig. 8. Empirical curve of ideal distribution

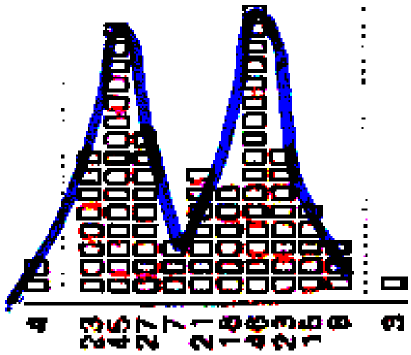

Fig. 9. Empirical curve of actual distribution

VI. CONCLUSIONS

Statistical control of machine elements is a modern control method, based on mathematical statistics relations. This takes the responsibility of passive control, active control or the control of machining safety on machine tools, for the case of large scale or mass series production.

The actual control can be made using diverse measuring devices and with different accuracies depending on the importance and purpose of the respective parts.

The paper presents three measuring equipments (the orthotest, the digital-analog system and the digital micrometer connected to the statistic printer) and three methods for data acquisition, processing and analysis (hand calculation, using the computer and by specialized device for statistical calculus and results printing).

To be mentioned that some differences were obtained concerning the classes and values for the calculated statistical parameters (mean and standard deviation). It is normal as measuring devices with different precisions were used. Moreover, the diameters were not measured strictly in the same zone and, hence, the influence of circularity and cylindricity deviations was also possible and consequently the classes' intervals were slightly different.

As a general view, the results are not incongruous but they support mutually and from this point of view all the three methods present viable results.

Nevertheless, each method presents advantages and inconveniences.

1) By hand processing of the results obtained with orthotest:

The method is suitable especially from instructive and didactic point of view. It helps in understanding the method, is simple, the precision is adequate and does not require expensive apparatus or sophisticated equipment. The disadvantages are related to the time consuming phases such as adjustment, measurement and especially the calculations and graphical plots. To diminish these drawbacks it is recommended a computer.

2) Processing on computer the data acquired with the digital-analog system:

The method presents high precision, allows for direct data recording on computer (for instance, using Excel utilitary) which increases the calculation accuracy and reduces significantly the time necessary for it. The weaknesses of the method are related to the adjusting time and the necessity of relatively complex equipment and inherent high costs.

3) Automatic results processing using the digital micrometer connected to the calculation and printing device:

The method ensures an adequate precision. It allows easy reading of results due to the digital display, it doesn't require computer or printer, the calculations and plots are automatically made and the working times are reduced.

As a disadvantage it can be mentioned the relative raised price of the device, connecting cables, measuring instruments and specialized software, possibly.

We must mention that the manufacturing company realized dedicated software and by connecting a data cable, other statistical processing can be made on measurement results (normality tests, tests on aberrant character of measurements etc.).

Future researches could continue measuring parts from an actual machining process, using either the digital calliper either the digital micrometer, for a greater batch (300-500 parts) or even for up to 9999 parts for a rigorous statistical approach.

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