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DETERMINING THE DISTRIBUTION CURVE OF A SET OF PARTS THROUGH IMAGE PROCESSING IN LABVIEW

Vlad Gheorghiță

National University of Science and Technology POLITEHNICA Bucharest, Department of Manufacturing Engineering, Splaiul Independentei no. 313, sector 6, 060042, Bucharest, Romania

Corresponding author: Vlad Gheorghiță, vladgheorghita90@gmail.com

Abstract: In this paper through image processing techniques, for a batch of 100 workpieces machined with a new cutting tool CoroCut XS adjusted to the dimension on an automated lathe SARO 16, will be determined whether their dimensions fall within the defined tolerance range. To measure the desired dimensions, the images of the parts are obtained through a system equipped with a video camera and then a software application is made using a virtual instrumentation software LabVIEW and NI Vision Assistant module in which the captured images are analyzed through several filters by removing some color planes to better define the objects or by achieving a good contrast with the background. Then in the process of image analysis some small objects from the images are removed that will negatively affect or some holes that may appear on the perimeter of the part are filled. The images of the cylindrical pieces will be acquired with a smart vision camera that digitizes the images and process them in a real-time manner. The camera used is ESP32, a system-on-chip microcontroller with integrated Wi-Fi. This camera could be placed in working position over the processed surface or can be used to take an image after the part was processed. The classic method of measurement through a measuring instrument called orthotest will be replaced by an image analysis and processing technique. The created applications will determinate the distribution curve of a batch of machined parts with the adjusted tool and will interpretate the studied features.
Key words: Image processing, LabVIEW, normal distribution, virtual instrumentation, measurement.

1. INTRODUCTION

Automated lathes are intended for machining from the calibrated bar of parts of medium complexity where the ratio between the length and the diameter is between 2 and 5, parts that have several concentric exterior and interior surfaces having wide use in the machine building industry, as well as in the automotive industry. This type of equipment is provided with 3, 4 or 5 transverse sleds and a revolver head perpendicular on the axis of the main shaft for which there are 6 to 8 bores in which the cutting tools are fixed.
The purpose of this paper is to analyze a set of 100 parts from copper-zinc alloy, with cylindrical shape, processed on a lathe with a new cutting tool CoroCut XS adjusted to the dimension. A system was designed and then with the help of a camera ESP32, images of the pieces are acquired in real time. With LabVIEW software and the related Vision Assistant module, a software application was developed that determines the diameters of these 100 pieces and then it is verified if the obtained dimensions are within the prescribed tolerance field.
In his research paper, Dhikhi [1] made the identification of an object based on images taken in the same scenario without and with the object present in an image. The identified object is distinguished by the size of object area displayed and their coordinates. Jiwane [3] demonstrates how real-time measurements may be calculated and how objects can be recognized using an IoT video device. An IoT-based real-time object measuring technique for calculating measurements and dimensions of objects is proposed based on NumPy and OpenCV libraries, with the following steps: capture a picture, measurement of an object, calculating the area, saving and displaying the measurements. The research proposed in [6] shows the utilization of image processing technique to calculate the size of an object with the laser beam technology based on the numbers of pixel present between laser spots. The proposed technique is based on the concept of image perspective in which one can observe that as the distance of an object from the observer increases, the observer feels that the object is shortening.

2. MATERIALS AND METHODS

A machine vision system typically consists of machine vision software (machine vision tools) and a camera (device for image acquisition). None of the components can be isolated or segregated (illumination, camera,

lens optics, field of view, calibration). To measure the dimensions for different types of pieces is time consuming, inaccurate and expensive. The use of machine vision makes it possible to complete this process more quickly, accurately and with low cost. Because ready-made applications require additional budget, developing one's own application has the benefit of cost savings.
The 100 experimental pieces that will be measured have the diameter of 8,8 mm, superior deviation + 0.008 mm and inferior deviation - 0.015 mm (figure 1).

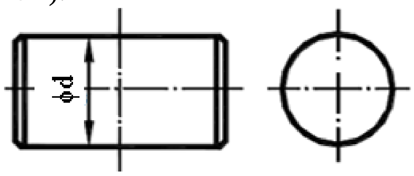


Fig.1. The pieces in the batch (100 pieces) in the measuring position

The study of the distribution of actual dimensions or deviations, proceed as follows: a batch of 100 pieces was processed using the same tool. In a classic approach, with a precision instrument such as an orthotest, the size of each piece of the batch is measured and recorded in the order of measurement. In the approach proposed in this paper, the orthotest will be replaced with a camera. The dimensional control of the part’s diameter was made in static mode with the development perspective of automating the process in a manufacturing line. Automated inspections and intelligent image analyses drastically reduce production costs and optimize quality control processes. The pieces are positioned in an established area, the camera placed on the system will acquire the images of each part.
It is a measuring system with the possibility of movement in two directions to be able to measure the parts placed on the table of the equipment in the form of a 10 × 10 grid, as in figure 2. The positioning on top of each part is done with the help of stepper motors.

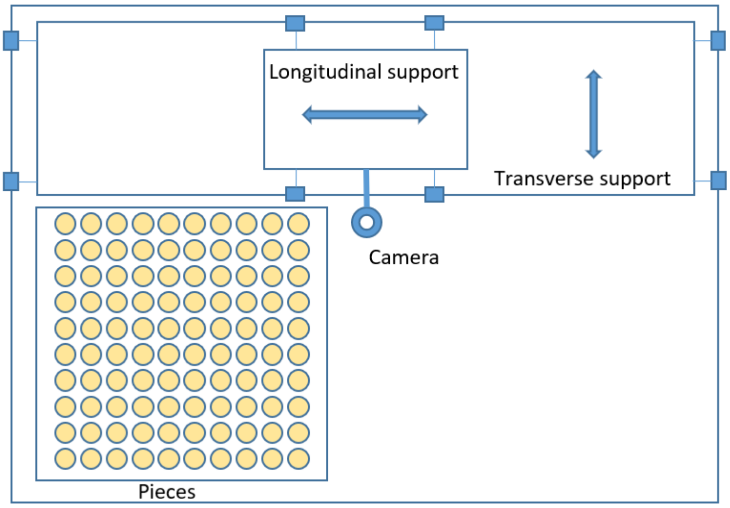


Fig. 2. Measurement system

There can be several categories of technological process depending of the analyzed parameter (figure 3): unstable technological process - the variation of the value of the examined characteristic is strongly influenced by the existence of one or more systematic factors; static technological process stable - the values obtained for the examined characteristic, for all components of the product batch, are distributed according to the normal law (Gauss); stable dynamic technological process - for all processed lots the characteristic values have the same value for the arithmetic mean and the same value for the quadratic mean deviation; stable technological process as a setting - the arithmetic mean of the characteristic values is permanently maintained at the same value for all batches; technological process stable in precision - only the mean square deviation is permanently maintained at the same value for all batches; unstable technological process both in terms of adjustment and accuracy - both the arithmetic mean and the square deviation do not remain constant [4].

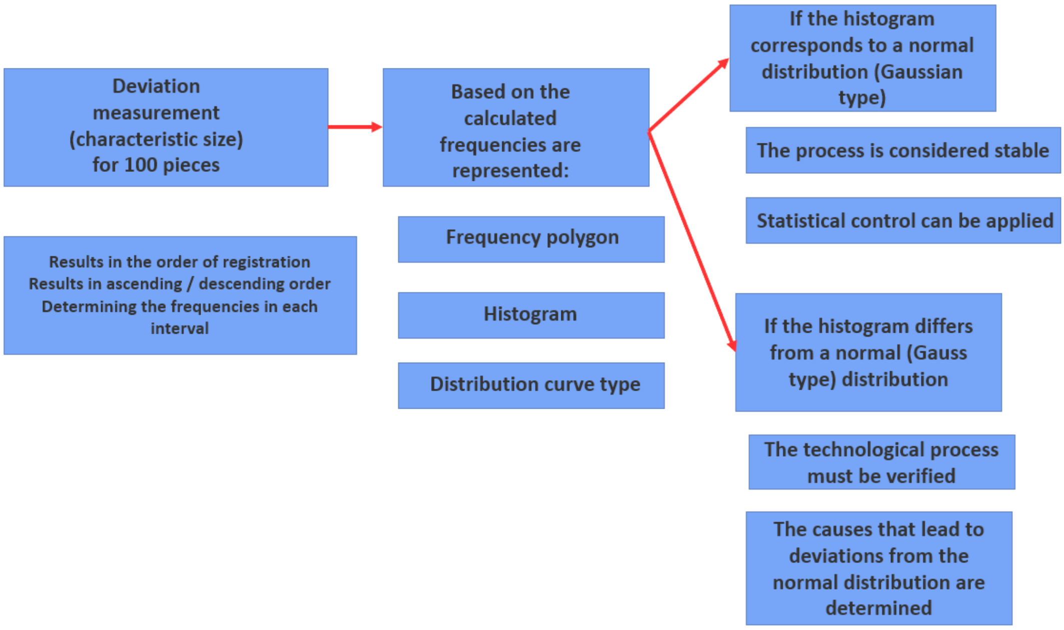


Fig.3. Logic diagram for checking the static stability of the technological process

3. NI VISION ASSISTANT AND LABVIEW APPLICATION

NI LabVIEW is a graphical program development environment and represents a powerful tool used by scientists for various kind of measurements or process controls [5]. NI Vision is a library included in the NI Vision Development Module for LabVIEW and is meant for the development scientific imaging applications and machine vision.

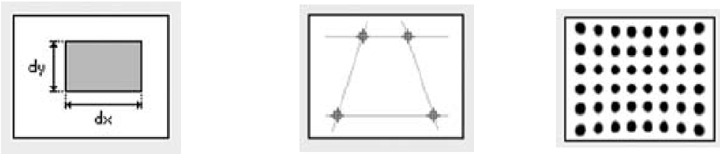
Setting up the imaging system is the part most important for developing a vision application. Before an image is acquired, the imaging environment should be favorable for the image analysis method. The image environment should produce image with enough quality to extract the information needed [5]. The type of camera being used, the camera's lens, its resolution, and the ambient illumination must all be taken into consideration [7]. Always set up the camera so that it is perpendicular to the object analyzed. Although the software is able to correct the perpendicularity issue, it is advised that the camera be positioned as precisely to the object as possible. NI Vision supports cameras ranging from simple web cameras to complex GigE Ethernet cameras.

The images of the cylindrical pieces were acquired with a smart vision camera that digitizes the images and process them in a real-time manner [5]. The camera used is ESP32, a development board that uses PCB on-board antennas and cores based on ESP32 chips. It can work independently as a minimum system. ESP32 integrates WiFi, 2 high-performance 32-bit LX6 CPUs, main frequency adjustment ranges 80 MHz to 240 MHz, on-chip sensor, Hall sensor and temperature sensor. This camera could be placed in working position over the processed surface or can be used to take an image after the part was processed. The images were taken in a controlled environment in terms of brightness and contrast for the proper operation of the image processing algorithm and the elimination of possible noises. The images acquired with the camera are stored in a folder and then they will be analyzed and processed.

In image processing applications for the measurement of some dimensions, the action of calibrating the entire system is crucial [7]. There will be some perspective issues if the camera axis is not parallel to the object. The acquired image may be affected as a result of this type of inaccuracy depending on the proximity and angle of the objects to the camera. To reduce perspective errors, the alignment of the camera’s axis with respect to objects is very important. Therefore, distortions that are caused by optical errors in camera lens can occur [8]. These distortions can be corrected by using NI Vision calibration instruments. To convert pixels to real-world dimensions, conversion data can also be acquired during the correction process. Visual analysis techniques will allow for determining the location of objects and measuring their dimensions and dimensions in physical units [7].

By calibrating an image through a measuring instrument such as a ruler or a user-defined calibration grid pattern, it is possible to get conversion information in real-world units not in pixels, as well as corrections for distortion of the image with calibration tools. To correct possible errors in the acquired images, the file whic contains the embedded calibration information will be used (figure 4).

Simple calibration (point distance calibration)	Calibration using user-defined points	Grid calibration (Distortion Model, Camera Model)
Camera setup is in the vertical direction and distortion is neglected. By using preknown *x*- and *y*-direction length, pixel to distance ratio can be obtained.	By using the real distance of user-defined points, image can be calibrated.	By using grid information, distorted image can be calibrated and pixel distance can be converted to real distance.



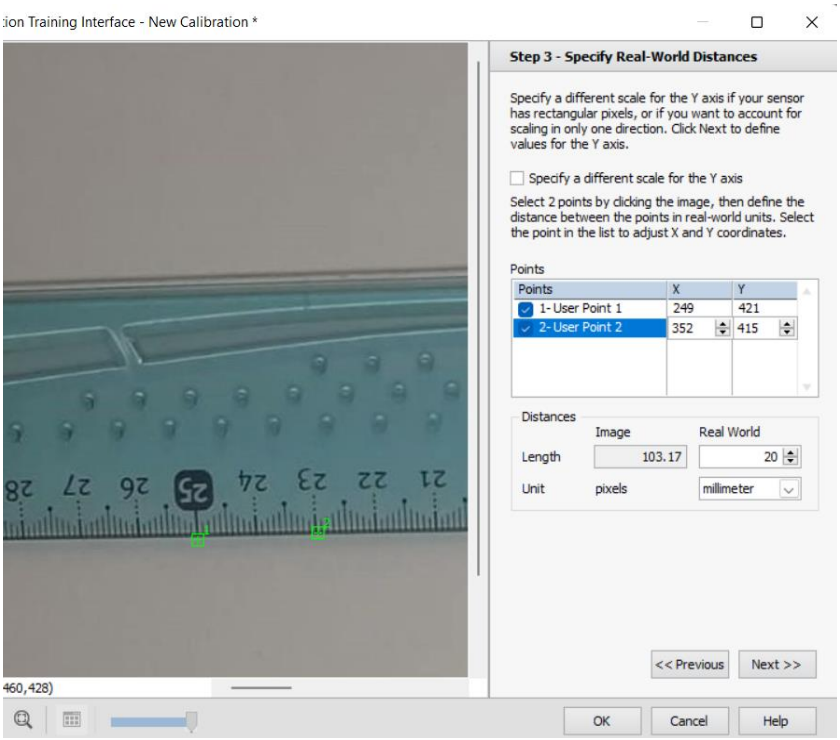


Fig. 4. Calibration method in NI Vision Assistant

It is possible to acquire or read an image from an image acquisition device, like a camera, from an image saved in a computer directory, or by converting a 2D array into an image. The captured images are analyzed by removing some color planes from the images to create a better contrast between the objects and the background. This will improve their definition. Then few small objects that may negatively affect the image can be removed. Also, some holes in the part's perimeter some holes can be filled, which may appear as small objects in the image. After the calibration process is concluded, the particle analysis highlights complete objects and not just parts of an object [2]. It is difficult to measure the size of a specific part of an object. Edge detection can be applied to a large number of search lines that are used to browse a 2D area in order to achieve the purpose. Since the contour of an object can be determined by using numerous lines to define the 2D area across a region of interest (ROI), measuring an object's dimensions in this way can provide precise information [4].
In NI Vision Assistant software, the Clamp function using 2D edge detection algorithm is used to detect locations that identifies the minimum or maximum length of an object. This function for measuring works only with 8-bit images. The Reposition Region of Interest option must be enabled to link the region of interest specified to a previously defined coordinate system. The region of interest (ROI) must be linked to a coordinate system if the position of the object under inspection changes from one image to another, and the position of the region of interest need to be adjusted to match the new location [5]. In the Edge Strength Profile part, NI Vision Assistant displays the average of the line profile of all the lines used for edge detection. The image should be displayed on the screen after the image acquisition is done. The LabVIEW VI created through the script developed in NI Vision Assistant is shown in figure 5.

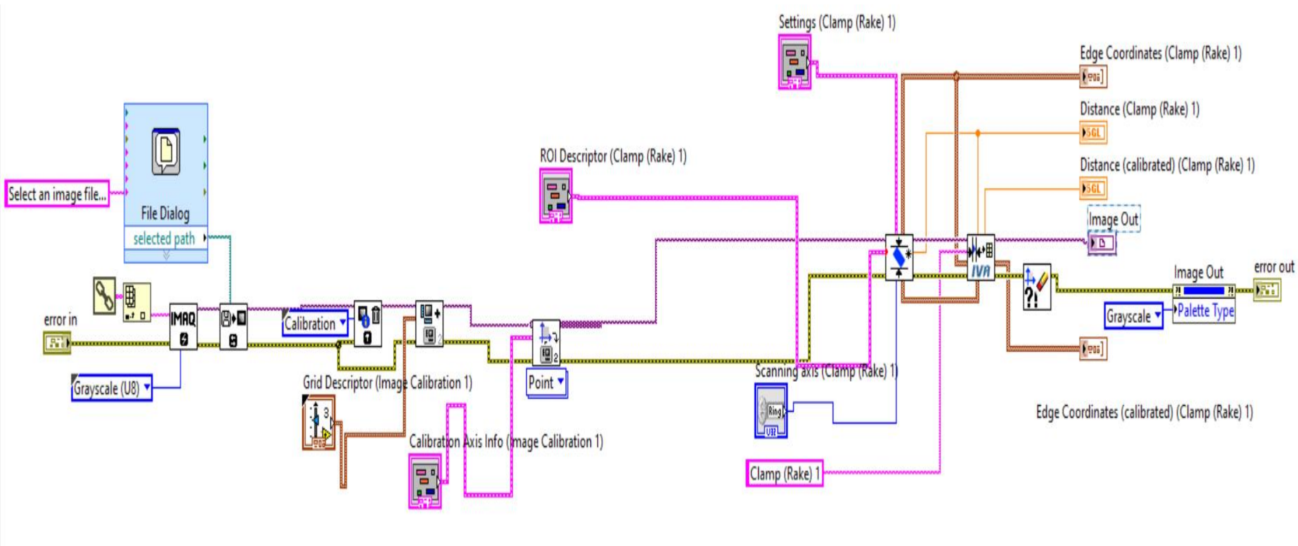


Fig. 5. The Block Diagram of LabVIEW application for image processing

For results interpretation, another LabVIEW application was designed. To be able to interpret how the processing was done it is necessary to systemize the dimensions for the 100 parts (table 1) in increasing order.

Table 1. Sorted diameter measured for the pieces [mm]

Part number	***[1-10]***	***[11-20]***	***[21-30]***	***[31-40]***	***[41-50]***	***[51-60]***	***[61-70]***	***[71-80]***	***[81-90]***	***[91-100]***
Values	8.785	8.786	8.788	8.791	8.794	8.796	8.798	8.8	8.802	8.805
	8.785	8.787	8.788	8.791	8.794	8.796	8.798	8.8	8.802	8.806
	8.785	8.787	8.788	8.791	8.794	8.796	8.798	8.8	8.803	8.806
	8.785	8.787	8.789	8.791	8.794	8.796	8.799	8.8	8.803	8.806
	8.785	8.787	8.79	8.792	8.794	8.797	8.799	8.8	8.803	8.807
	8.785	8.787	8.79	8.792	8.795	8.797	8.799	8.801	8.803	8.807
	8.785	8.787	8.79	8.792	8.795	8.797	8.799	8.801	8.803	8.807
	8.786	8.788	8.79	8.793	8.795	8.797	8.799	8.801	8.804	8.807
	8.786	8.788	8.79	8.793	8.795	8.798	8.799	8.802	8.804	8.808
	8.786	8.788	8.79	8.794	8.796	8.798	8.8	8.802	8.805	8.808

With the purpose of systematizing the actual dimensions, 0.5% of the random or non-random errors are eliminated and the amplitude of the intervals is calculated. The number of intervals are established and the array of values corresponding to the ends of the intervals is formed. The Front Panel of the LabVIEW application is presented in figure 6.

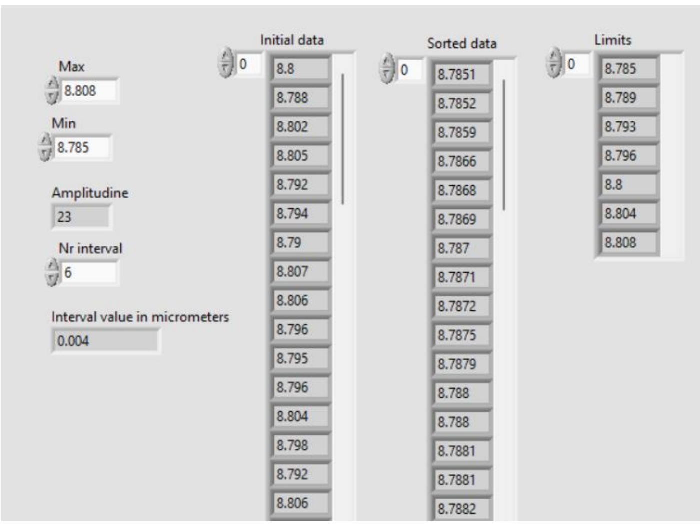


Fig.6. The Front Panel of the LabVIEW application for data processing

4. RESULTS INTERPRETATION

With the values obtained through the measuring chain, the graph of the empirical distribution is represented, proceeding as follows: for each dimensional range, the values x_i is taken in the abscissa, and in the ordinate the values of the frequencies, then the points will be united to obtained for each pair of values (x_i, n_i) thus building up the frequency polygon. The absolute frequency of the interval means the number of dimensions found in the same interval. Considering that within the distribution the number of intervals is infinitely increased, while restricting the respective intervals, the broken line or the polygon of frequencies will be converted most of the time, into a continuous bell-shaped curve (theoretical curve of normal distribution).
If the amplitude domain, the number of intervals increases infinitely and simultaneously limits the intervals, the broken line of the frequency polygon will convert into a continuous bell-shaped curve, the theoretical curve of the normal distribution (Gauss-Laplace curve). The distribution of the actual dimensions of the diameters when machining the pieces with the tool adjusted and their amplitude, have the meaning shown in figure 7.

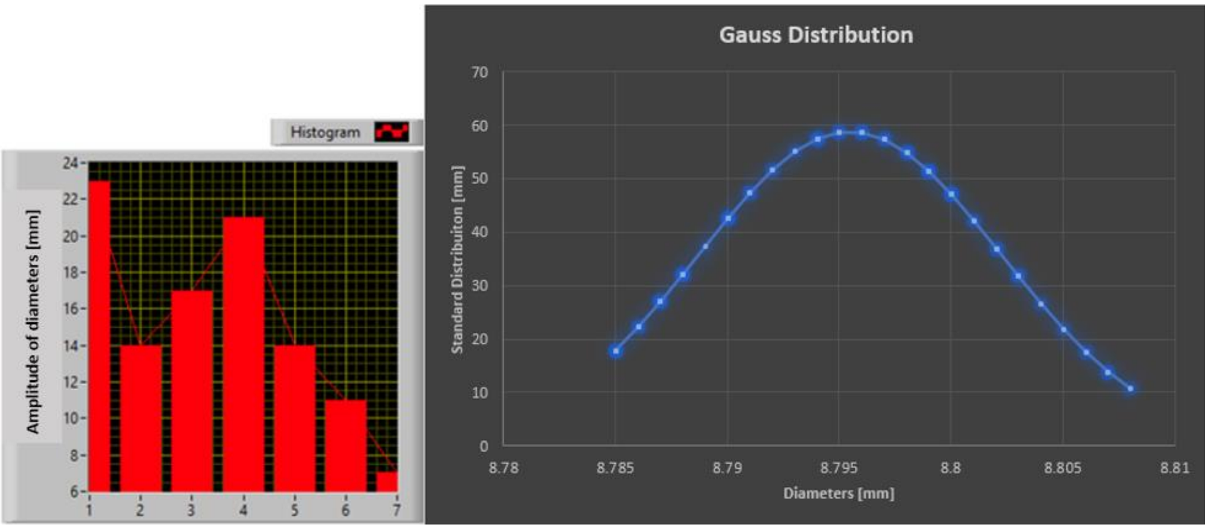


Fig.7. Histogram and Gauss distribution of the diameters

From the empirical distribution diagram and the practical activity, the following conclusions can be drawn: the central intervals have frequencies greater than the lateral intervals, at which the frequency decreases gradually, the distribution of the dimensions takes place on both sides of the central value. This is due to the action of random errors whose magnitude and sign are randomly variable.
It is calculated the scattering field 6σ that also referred at the characteristic precision of the machine tool. Average value $\bar{x}$, frequency n_i, and the range of values 6σ characterize the way processing was done. To see if the processing satisfies the prescribed elevation, the tolerance delimited by the d_{min} and d_{max} diameters prescribed in the drawing can be displayed on the same scale. The frequency range is also used to graphically represent the absolute or relative frequency distribution when the data has been systematized after a continuous or discontinuous numerical feature. To construct it, each perpendicular value of each characteristic value or interval center is raised and the point at a distance equal to the frequency of that variant or range. Joining all the points thus found results in a frequency polygon. By processing the results obtained through image analysis, it was highlighted that the size distribution can fit into a normal distribution (Table 2).

Table 2. Statistical results

Standard deviation σ [mm]	6σ [mm]	$\bar{x}$ - 3σ [mm]	$\bar{x}$ + 3σ [mm]
0.0068	0.04	8.78	8.82

Since the average value $\bar{x}$ corresponds to the axis of symmetry of the normal distribution curve, it means that it will always indicate the actual position of the curve, which position, in practice, depends directly and exclusively on how the tool was adjusted to size. Because of random errors, not systematic errors, the dimensions will be distributed around the value the tool was set to.

5. CONCLUSIONS

Using image processing techniques (extract color plane, edge detection, image calibration and measurement), it has been demonstrated that these methods represent a reliable option for faster determination of requirements and for replacing classic measurement and control devices. With well-defined image acquisition system and the right lighting, the results obtained by image processing are similar, with an error of less than 5 % compared to the values determined with the classic procedure. In the analyzed case with the dimensions obtained through image processing, the average value $\bar{x}$ is equal with the medium size. If the scattering field 6σ would have been greater than the prescribed tolerance, it is recommended to move the processing to a more accurate machine tool or, if this is not possible, to adjust it so that the failure, which would objectively appear to be recoverable ($d_{ef} > d_{max}$ – for shafts). In future research, the created system will be applied to different types of parts with various shapes, sizes and materials in different lighting conditions.

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