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INNOVATIVE METHOD FOR MEASUREMENT OF GEOMETRIC ACCURACY OF MACHINE TOOL

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Abstract: *The paper presents an innovative method of data processing with the measurement device – Ballbar QC20W. The program for data transformation was created in Visual Basic.NET and it uses Fourier transformation for spectral analysis of measured profile. The paper presents the measuring method of CNC machine tools using Ballbar QC20W. There is a strong connection between the qualitative parameters of machine tools and the qualitative ones of the products (tolerances, roughness, etc.). It is very important to hold the stability of qualitative parameters of products as a key factor of production quality. The accuracy machine tools evaluation and prediction are of high interest and therefore is also importance to evaluate the accuracy of machine tools and make prediction of possible accuracy. How to detect the accuracy of CNC machine tools, various industries are becoming the user acceptance and maintenance of CNC machine tools much attention to problems.*
The paper deals about aspects of diagnostic accuracies CNC machine tool as well as with the possibilities of measuring methods and CNC machine tools using multi-parametric diagnostics. Main part evaluates possibility the geometric accuracy of CNC machine tool by specialize developed software's for compared with a direct (Ballbar QC20) and indirect (Talyrond73) method of measurements.

Key words: *Ballbar QC20-W, geometric accuracy, data transformation, direct measurement method.*

1. INTRODUCTION

To improve the accuracy of machined parts, it is necessary to increase the accuracy of the machine tool. There are various techniques available to establish the error and calibration of the CNC machine but every technique has its own limitations. The total ballbar device is useful for measurement in all axes [6].

Leading manufacturers of machine tools try to ensure that the machine will have the same properties (positioning accuracy, quality, etc.) in and out of cutting process, under certain conditions (tool wear, cutting speed, feed etc.) [5]. However, it is questionable whether the machine tool maintains those properties for machining parts in different places and at different technological parameters.

The technology accuracy is one of the keystone parameters in machining. There are many factors that affect achievable accuracy during the machining process. However, the first and most important one is the construction of the machine tool [3].

It is questionable whether the machine tool keeps this property for machining parts workable in different places and at different technological parameters. [4]

The machining accuracy of the part is influenced by technological system (machine – tool – work piece), as well as by the external environment (environment temperature, pressure, vibration and etc.) [1, 5]. For identifying geometric accuracy, this is usually measured on an unloaded (machine unload machining) machine tool.

When the CNC machine tool precision is to be measured not only one diagnostic method can be used, but also the multiparametric approach too. It is difficult to select the suitable measurement methods by multiparametric diagnostics in order to achieve the rating of the machine in the shortest time and with the lowest cost as well. These methods are independent and their evaluation has synthesized character. One more expensive method can be replaced by one less cost-intensive method.

The geometric accuracy of CNC machine will depend on various technological conditions as well as the location of the machined part on a worktable. Geometrical accuracy of produced part and its course time should be correlated with the precision of machine tool.

The state of a machine tool has an enormous impact on the quality of the piece, on which the machining process takes place. Therefore it is important to keep the machine tool in conditions that allow producing parts that meet the demanded accuracy. Very low tolerances or very high quality surface can cause unnecessary production costs, whereas high reliability and long-time use are recommended. In contrast, products with low prices have a positive impact on enterprise competitiveness.

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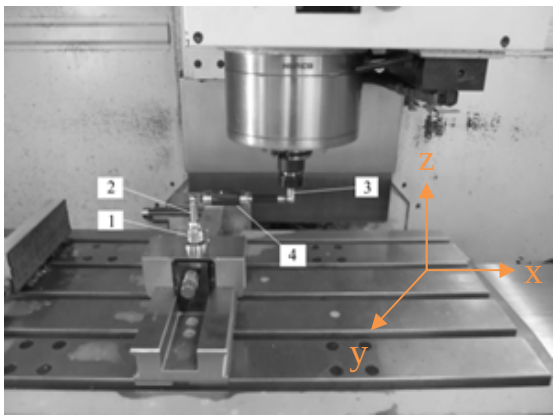


Fig. 1. Measuring device Ballbar QC20 – 1. Magnetic center holder, 2. Magnetic centre cup attached to rack, 3. Magnetic centre cup clamped in collet, 4. Measuring device.

2. DIRECT MEASUREMENT METHOD

Direct measurement method is suitable for unloaded machine which is not affected by impacts of the machining process. This measurement method obtains information about the current machine state.

Two devices were used for measuring unloaded machines (not during machining). Both devices have almost the same construction; one of these is a newer version. Full identification of device is Renishaw Ballbar QC10 or QC20W (see Fig. 1). Plot errors can be caused by machine errors and test errors. Machine errors are errors or faults in the machine under test. Ballbar QC20W has a higher reading speed and Bluetooth. Another advantage of the newer version is the possibility of concluding a working space of the machine.

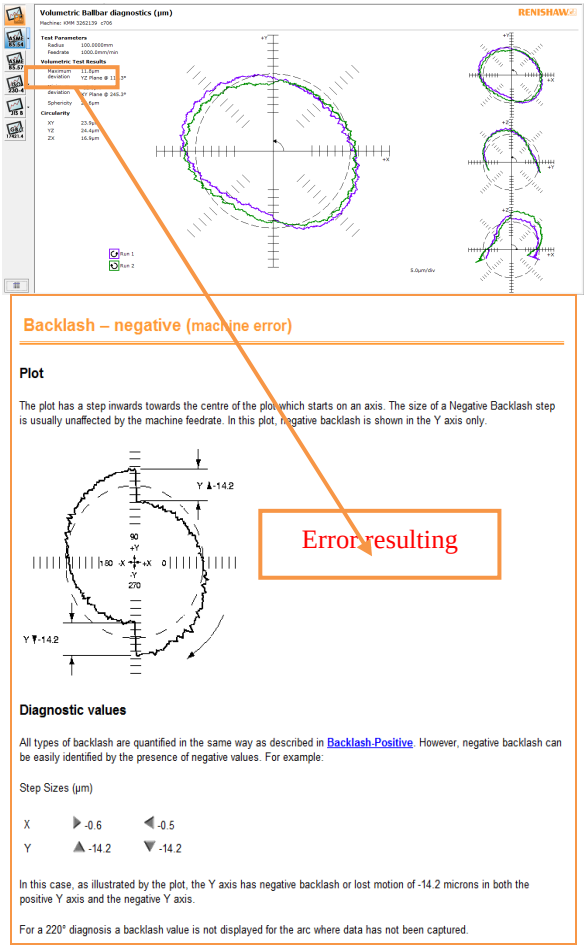


Fig. 2. Background software Ballbar – Error resulting.

3. PROGRAM CONVERTER-TEST FOR PROCESSING DATA FROM BALLBAR QC20

In the evaluation of ballbar QC20 results data from the software ballbar 20 was used. The final processing was done in the Microsoft Excel software, where the data is decomposed to harmonic components of the profile. In the program ballbar 20 is evaluated according to ISO 230-4:2005 and results from the program were used to verify the results processed in Excel. Because of the incompatibility of the measurement records from the software Ballbar 20 and Microsoft Excel a convertor in the programming language Visual Basic.NET was created. The program is able to convert *.B5R files to *.Sig (See Fig. 2). During the conversion the program filters input data file because the file contains data for multiple measurements.

For evaluation only data gained during one turn without the starting and ending part of the machine tool movement was needed.

The machine can be affected by an angular error that causes run out of X or Y axis to the plane of the test during movement. That can be caused by lack of stiffness or obliqueness of feed guiding elements. This error results in dimensional errors of machined parts. That can be solved by verification of used compensations, checking of feed guiding elements and leadscrews, etc.

Accuracy trends can be predicted by using error values in percent obtained with software ballbar 20 (See Fig. 4). FFT analysis was used to show geometrical properties of the real profile. Using these data it is possible to get a more accurate idea of the future development of machine tool errors and its accuracy.

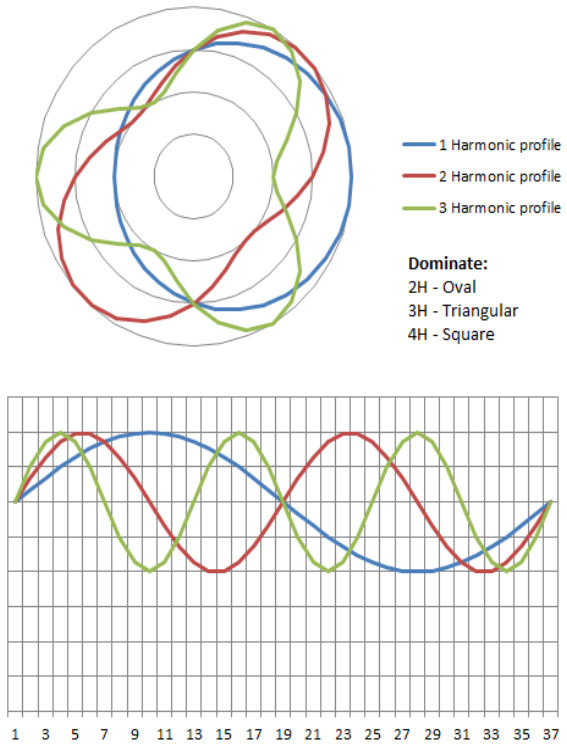


Fig. 3. Explanation of Harmonic profile.

The Renishaw Ballbar QC20 together with its software is used to measure geometric errors present in a CNC machine tool and detect inaccuracies induced by its controller and servo drive systems. If the machine had no errors, the plotted data would show a perfect circle.

The presence of any errors will distort this circle, for example, by adding peaks along its circumference and possibly making it more elliptical. These deviations from a perfect circle reveal problems and inaccuracies in the numerical control, drive servos and the machine's axes.

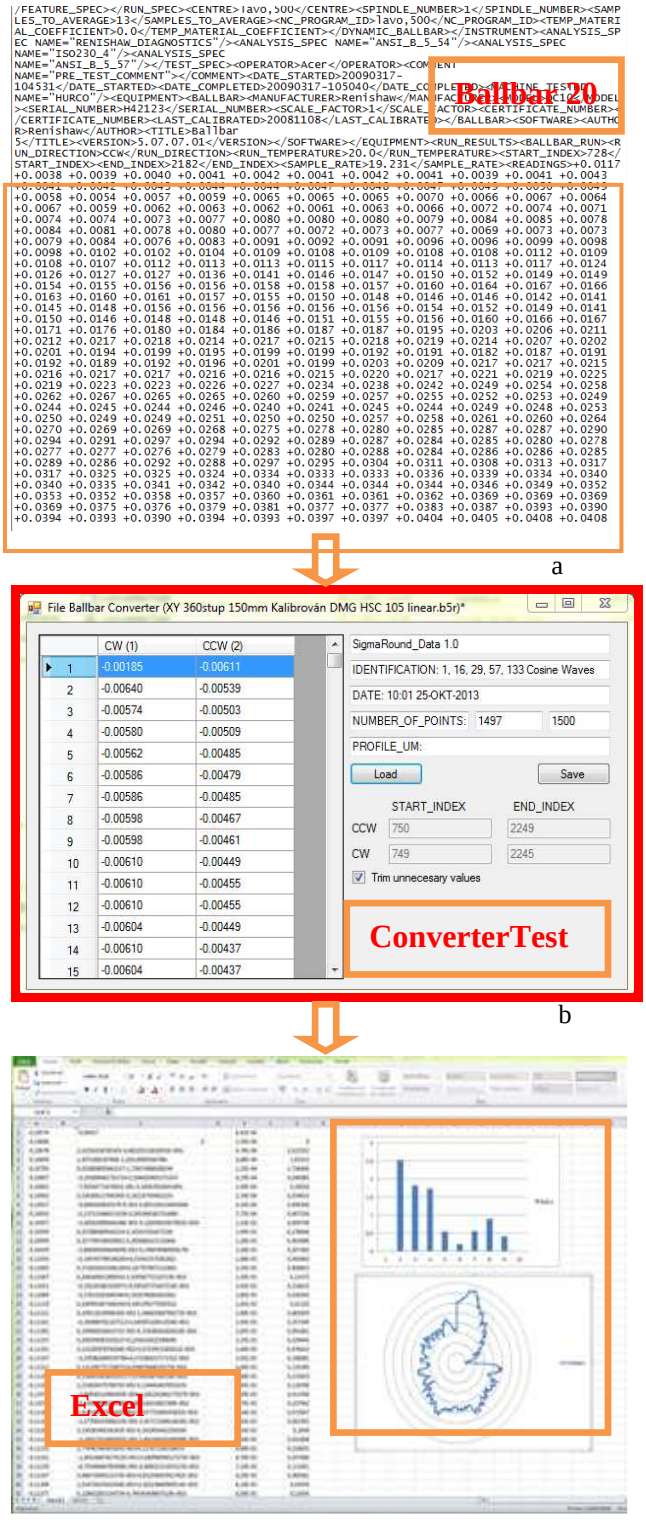


Fig. 4. Processing of harmonic analysis, when on the picture we can see procedure for processing data structure from Ballbar (a) to program ConverterTest (b) and output is Microsoft Excel (c).

During the data capture session, the Ballbar moves in a clockwise and counter-clockwise direction through 360° data capture arcs with 180° overshoot arcs. The items of hardware that are used during the test with a ballbar QC20-W [8] are the ones from figure 4.

3. INDIRECT MEASUREMENT METHOD

The Indirect measurement method for loaded machine tool (during machining) consists of test samples machined to required dimension and subsequent assessment by the measuring device. One of the most important factors will be that the sample is clamped by clamps and not by vice, because sample is deformed due to the applied force. It is necessary to eliminate force due tool entering sample, where it is necessary to use trochoidal milling.

Machine tool measuring (Fig. 5) is done at various places of worktable by different feed-rates (500, 1000, 1500 mm min^{-1}). Two positions where the measurement is carry out and machining are defined as central and peripheral location. The central location is near the middle of worktable and peripheral position in the upper left corner of the worktable. For each feed-rate of machine there are three samples, total number is eighteen samples.

Fig. 5. Sample after machining.

Fig. 6. Talyrond 73 measuring device.

The aim of the experiment is to machine the samples at prescribed feed-rate in position worktable. As a result we will compare the geometric characteristic, where we compare the correlation of deviations from roundness and harmonics profile machined parts and measured path.

5. PROGRAM TALI-TALI FOR PROCESSING DATA FROM TALYROND 73

The measurement is carried out at constant conditions. Experimental measurements are being performed on the machine tool Hurco VMX 30t when profile circularity of machined samples is measured by a measuring device TALYROND 73 (Fig. 6).

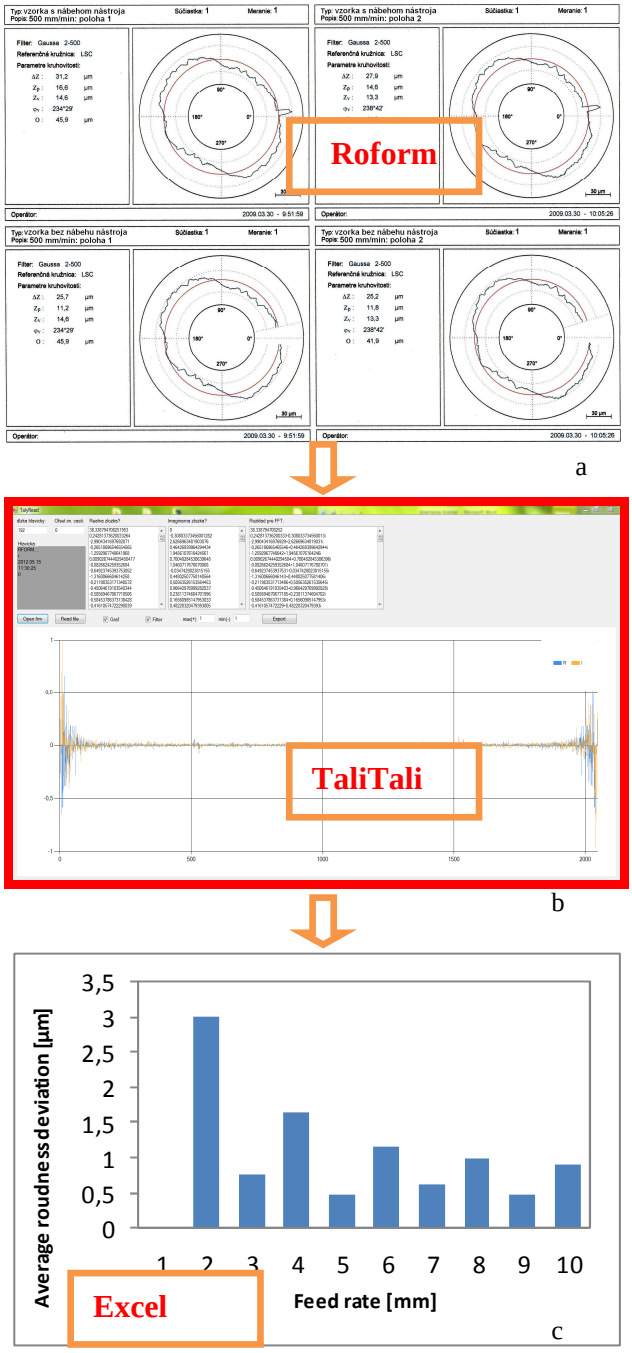


Fig. 7. Processing of harmonic analysis, when on the picture we can see procedure for processing data structure from Talyrond 73 (a) to program TaliTali (b) and output is Microsoft Excel (c).

The measurement is carried out in two positions at different and feed rates. The conditions are the same. The samples are machines in two positions at different and feed rates.

Measurement parameters are the same for both experiments; even if it can be difficult due the environmental conditions Roundness profile of machined samples are measured by measuring device TALYROND 73.

In the evaluation of Talyrond 73 results are use data from the software Roform. The final processing is done in the Microsoft Excel software, where the data is decomposed to harmonic components of the profile. The program Roform and results from the program are used to validate the results processed in Excel.

Output data from measuring devices files are written in a different format, so it is necessary to create a program that allows data processing and export in readable form. For this purpose the following program has been developed: Talitali (Fig. 7) for TALYROND 73 devices.

The data obtained is processed by measurement in Microsoft Excel, which are compare using the graphical display profile Roundness, are using Fast Fourier decomposed into harmonic components and next correlations indexes between each measurement are calculate.

It is necessary to verify the procedures for the processing data measure and evaluation. Graphical results are compared through the ROFORM for Talyrond 73device. Mathematical verification is possible only by ROFORM.

6. RESULTS

These errors can be solved by the methods mentioned above. FFT analysis (Fig. 8) was used to show the real profile. The data acquired from machine tool may be used to determine a trend of machine tool precision. Using these data it is possible to get a more accurate idea of the future development of machine tool errors and its accuracy.

Comparing the measurements showed that the choice between direct and indirect method is not clear. It confirmed the fact that even if the manufacturer provides the same precision values at different positions, the actual accuracy in different positions depends on errors and wear of machine parts.

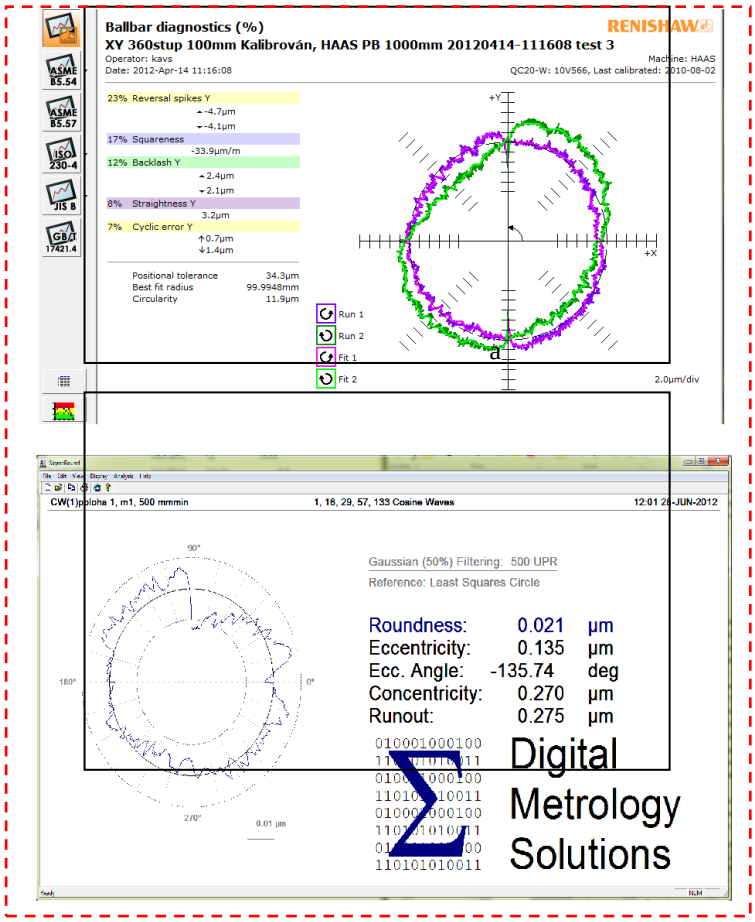
The machine error is reflected in the most common and most strained positions.

In the future, an evaluation of the implementation of maintenance in order to avoid the collision situation is strongly recommended.

One of the possible ways is the internal audit system of the maintenance process, where the company reaches an objective assessment of maintenance management. Draft measures designed to improve the process and implement corrective actions: (EN ISO 19011:2003).

7. CONCLUSIONS

The development of various methods for the measuring of machine tools is still a hot topic. There are a number of various methods deployed in practice, where individual devices are constantly improved. A significant development is the measuring of geometric parameters machine tool where multiple measuring devices are replaced with a single universal one. The progress in the



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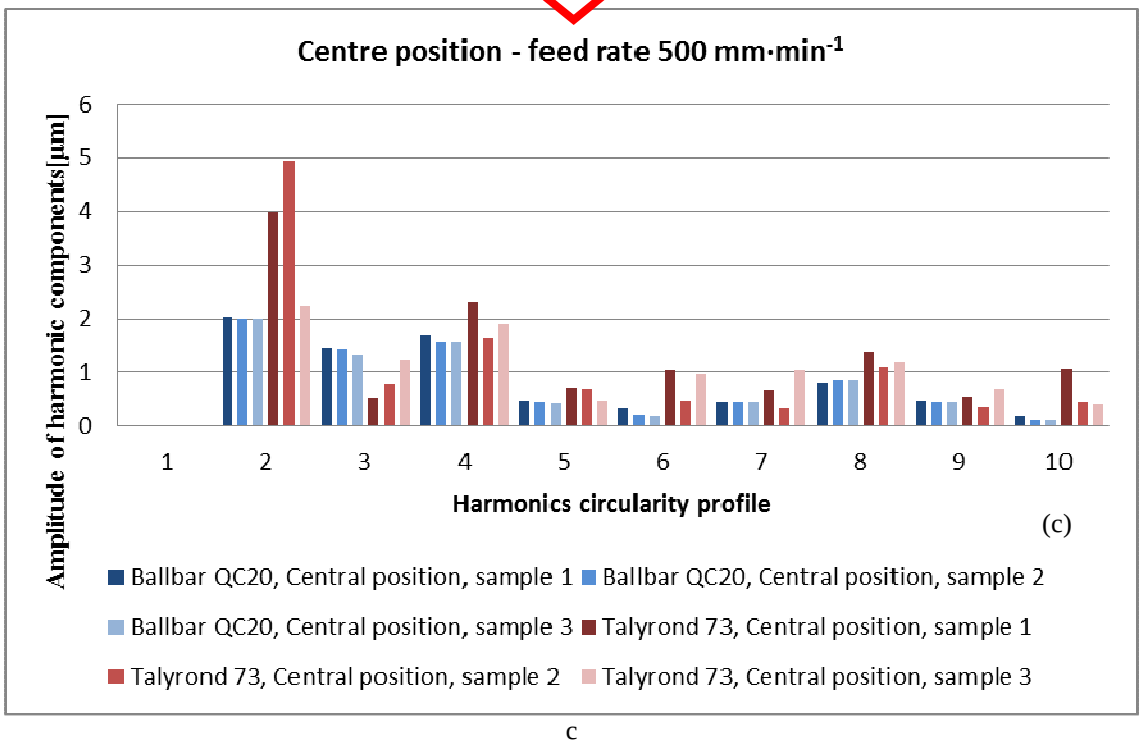

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Fig. 8. . Processing of harmonic analysis of software Ballbar 20 and Roform. (a) – ballbar 20, (b) – Sigma round, (c) – Excell.

development does not necessarily ensure wide use in the practice in Slovak manufacturing companies.

The quality of every component produced on a CNC machine highly depends on the machine's performance. Many inspection procedures take place after the component is produced, when it is too late to avoid scrap.

To avoid scrap it is better to check the machine before cutting any metal. Determining a machine tool's capabilities before machining, and subsequent post-process part inspection, can greatly reduce the potential for scrap, machine downtime and as a result, lower manufacturing costs. It doesn't matter if your machine is new or old, all have errors. Process control and improvement is the key to raising quality and productivity.

It is better to check the machine before cutting any material. Determining machine tool capabilities before machining and subsequent post-process part inspection can greatly reduce the potential for scrap and machine downtime and, as a result, lower manufacturing costs. It doesn't matter if your machine is new or old, all of them have errors. Process control and improvement is the key to raising quality and productivity.

The experiment consisted of measuring the precision of the machine tool by Ballbar QC20W (direct method) and Talyrond 73 (indirect method) which is used to measure the circular error. The machine tool was not machining during the measuring of circular error.

The output data from the measuring device files is incompatible with our software so it was necessary to create a program that allows data processing and exports it to readable form. For this purpose the following programs have been developed: ConverterTest and TaliTali intended for Ballbar and Talyrond devices. This program is also applicable in other experiments performed by the mentioned measuring devices.

The data obtained by measurement was processed in Microsoft Excel and compared using the graphical output. The measured roundness profile was decomposed into harmonic components using Fast Fourier Transform.

After that, the correlations indexes between each measurement were calculated. It was necessary to verify the procedures for the measured data processing and evaluation. Graphical results were compared through the SigmaRound software for Ballbar devices.

This article we draw attention as affected by the accuracy of machine tools for working in different parts of the work table. In the future, the data obtained from the measurement of machine tools used for creating your own expert system. For the creation software on an expert system is the ability to use existing software for the device Ballbar QC20 and Talyrond73. Expert system should be focused only the geometric accuracy of the CNC machine tool.

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