SOFTWARE POST-PROCESSING OF DATA STRUCTURE OBTAINED FROM MEASURING DEVICE BALLBAR QC20

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Abstract: *The paper presents the innovative method of data transformation from the measurement device Ballbar QC20W by specialized software. Program for data transform was created in Visual Basic.NET and it uses Fourier transformation for spectral analysis of measured profile. Paper deals with the measuring method of CNC machine tools using Ballbar QC20W. There is an influence between qualitative parameters of machine tools and qualitative parameters of products (tolerances, roughness, etc.). It is very important to hold the stability of qualitative parameters of products as a key factor of production quality. Accuracy evaluation of machine tools and make prediction of its future accuracy is of high interest.*
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 for error detection and machine tool calibration but every technique are having its own limitations. The total Ballbar device is useful for measurement in all axes. (Sata, 2010)
Leading manufacturers of machine tools try to ensure that the machine will have the same properties (positioning accuracy, quality, etc.) in and out of cut, under certain conditions (tool wear, cutting speed, feed etc.) (Svoboda, 2003). However, it is questionable whether the machine tool keeps this property for machining parts in different places worktable and at different technological parameters. (Bulej et. al., 2013)
The machining accuracy of the part is influenced by technological system (machine – tool – workpiece), as well as external environment (environment temperature, pressure, vibration and etc.) (Archenti & Nicolescu, 2013) - (Khan & Chen, 2009). For identifying geometric accuracy is usually measured on a unloaded (machine unload machining) machine tool.
When we measure the CNC machine tool precision there should be used more than one diagnostic method, but the multiparametrical approach too. It is difficult to select the suitable measurement methods by multiparametrical diagnostics to achieve the rating of the machine in the shortest time as well as with the lowest cost. These methods are independent and their evaluation has synthesized character. One more expensive method can be replaced by another less cost-intensive method.
Geometric accuracy of CNC machine will depend on various techno-logical 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 (Košinár, 2013).
Geometric errors in machine tools are caused by many factors, such as kinematic errors, thermo-mechanical errors, loads and load variations, dynamic forces, and motion control and control software (Schwenke et. al., 2008).
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 which allows producing parts that meet the demanded accuracy. Very low tolerances or very high quality surface can cause unnecessary production costs. Positive is high reliability and long-time use. In contrast, products with low prices have a positive impact on enterprise competitiveness (Košinár & Kuric, 2011).
Technology accuracy is one of the keystone parameters in machining. Many parameters affect achievable accuracy during the machining process. However, the machining parameters affect the process's accuracy, the first and most important thing is the construction of a machine tool (Beňo, et al., 2013).
For the accuracy determination of the machine tool, there are many different methods and it is difficult to decide which the right one is.

Testing and evaluating machine tool accuracy are critical operations to guarantee a high quality of machined parts, and represent a basic prerequisite for improving machining system performance (Khan & Chen, 2009). The existing standards regarding methods for the evaluation of machine tool accuracy refer to:

- Off-operational methods, which measure accuracy of a machine tool in unloaded conditions (e.g. ISO 230-1, ISO 230-2, for geometric accuracy of machines operating under no-load or quasi-static conditions, ISO 230-3 for thermal accuracy).
- In-operational methods, performed under machining operation, using test specimens, and relate their accuracy to characterize the machine tool capability (Archenti & Nicolescu, 2013).

This paper aims to evaluate of the transformation data structure obtained from measuring device Ballbar.

2. DIRECT MEASUREMENT METHOD

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

Direct measurement method or error quantification is built up on elemental basis and total positions dependent and position independent parameters can be measured and quantified individually. This approach addresses the problem of computing deformation of machine members individually because the errors of these parameters is usually impossible to analyse precisely by using some other techniques or methodology and quantification of elemental errors is the only possible solution which helps out to find the genuine major source, causes and their contribution in accuracy of machine tool (Khan & Chen, 2009).

Therefore, the major limitation of current methodologies for the evaluation of accuracy is the ability to further correlate geometrical, dimensional and surface deviations of machined parts to machining system capability.

Accuracy of machine tool is measured under unloaded conditions different methods, depending on the required parameters (such as positional accuracy - laser interferometer or Ballbar test, etc.).

3. BALLBAR QC20 – W

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 an ideal 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. During the data capture session, the Ballbar moves in a clockwise (CW) and counter-clockwise (CCW) direction through 360° data capture arcs with 180° overshoot arcs. The items of hardware that you will use during your test with a QC20-W Ballbar are shown in the Figure 1 (Renishaw help)

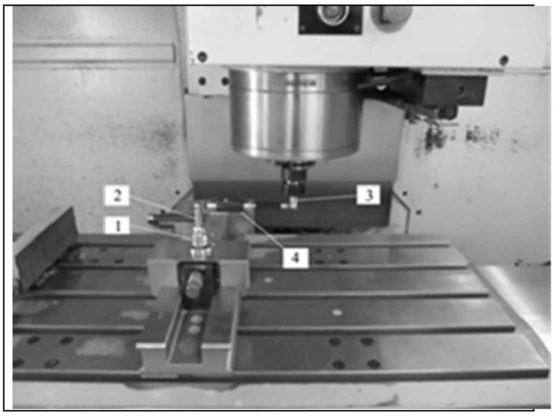

Fig.1. Measuring device Ballbar QC20 – 1. Magnetic center holder, 2. Magnetic centre cup attached to rack, 3. Magnetic centre cup clamped in collet, 4. Measuring device

The QC20-W allows machine calibrations to be conducted in the XY, ZX and YZ planes without having to setup and centre the machine between each test. Therefore, with one setup, machine volumetric performance can be evaluated using the volumetric analysis software. Renishaw diagnostics can be performed on data captured from the three planes, allowing machine errors to be revealed and identified.

The Ballbar moves two times in a CW and two times CCW because half past in a CW (CCW) run-up (run-down) machine tool (Renishaw help). The Ballbar 20 software can automatically

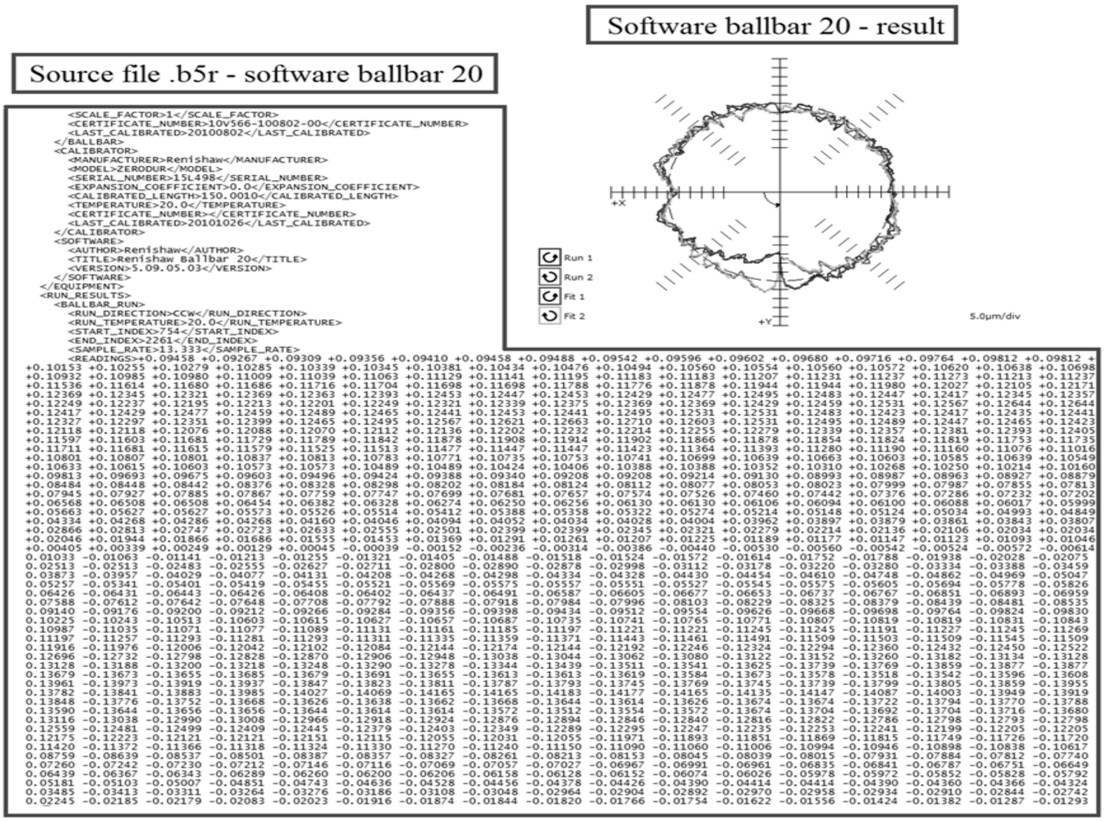

Fig.2. Software ballbar 20 – source code and roundness analysis

analyse 360º and 220º Ballbar plots and diagnose machine errors.

When analyzing the source files *.B5R (fig. 2) we understand how to write data files. In the file are written the test conditions (location Ballbar, feed rate, length Ballbar etc.) and record the values of the measurement in the direction of CW and CCW. To the transformation of data structure the source files we need to edit data. We remove part of the run-up and run-down tool path.

4. THE TRANSFORMATION OF DATA STRUCTURE

In the evaluation of Ballbar QC20-W results were used data from the software ballbar 20. Final processing was done in Microsoft Excel software, where the data is decomposed to harmonic components of the profile (Fig. 3). In the program ballbar 20 is evaluated according to ISO 230-4:2005 (ISO 230 – 4, 2005) and results from the program were used to verify the results processed in Excel. Incompatibility of measurement records from software ballbar 20 and Microsoft Excel was solved by convertor created in the programming language Visual Basic.NET. Program is able to convert *.B5R files to *.Sig (Fig. 4). Because the file contains data from multiple measurements the conversion program also filters input data file during the processing. For evaluation were needed only data gained during one turn without starting (run-up) and ending part (run-down) of the machine tool movement.

Machine can be affected by an angular error that causes runout 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 to 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 percents obtained with software ballbar 20. 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.

After processing and verification of transformed data from the software ballbar 20 was created analysis software of roundness deviations QC - convertor. The application was created in the open source program Lazarus. In the first step, QC convert reads data from a file. B5R (ballbar 20) and process it. (See Fig. 5) Using Fast Fourier Transformation (FFT) decomposed profile to the real, imaginary part and calculates magnitude and phase of individual harmonics. Backward composition of profile is realized by using a reverse FT polar diagram of this profile.

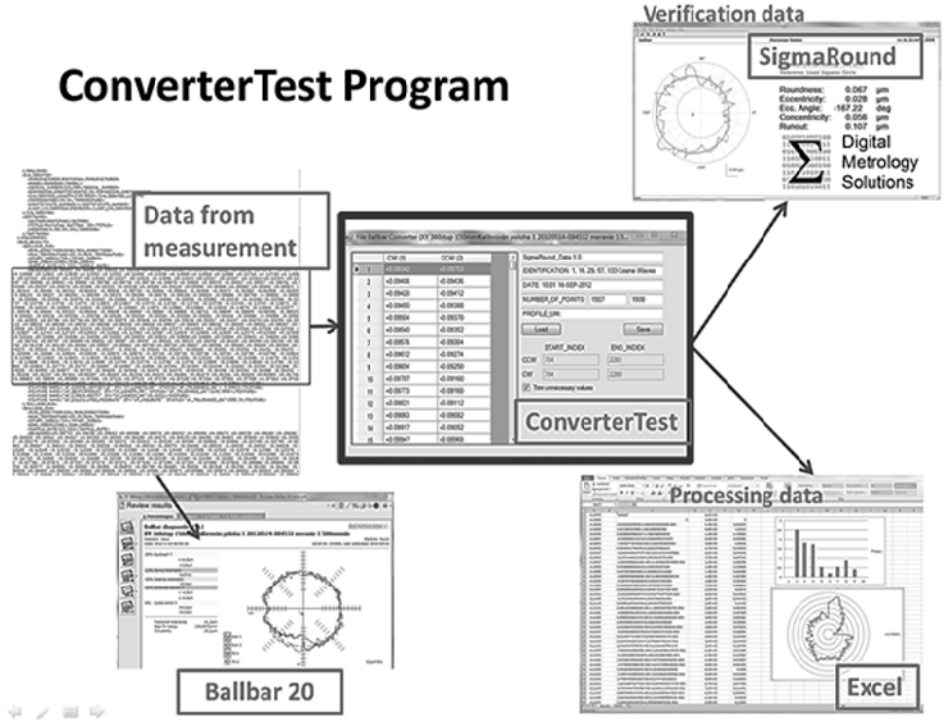

Fig.3. ConverterTest program

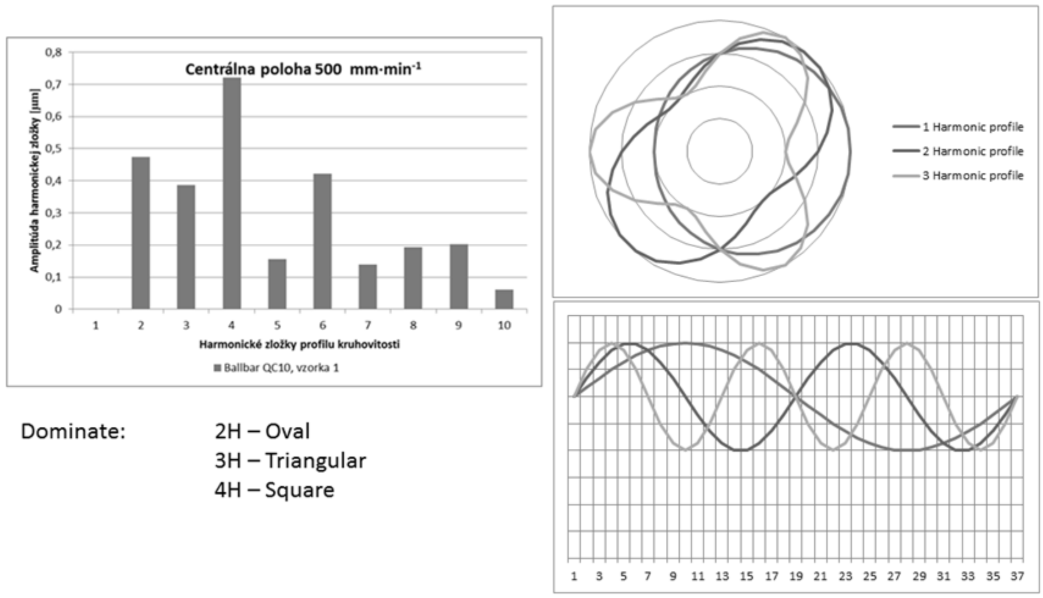

Fig.4. Processing of harmonic analysis

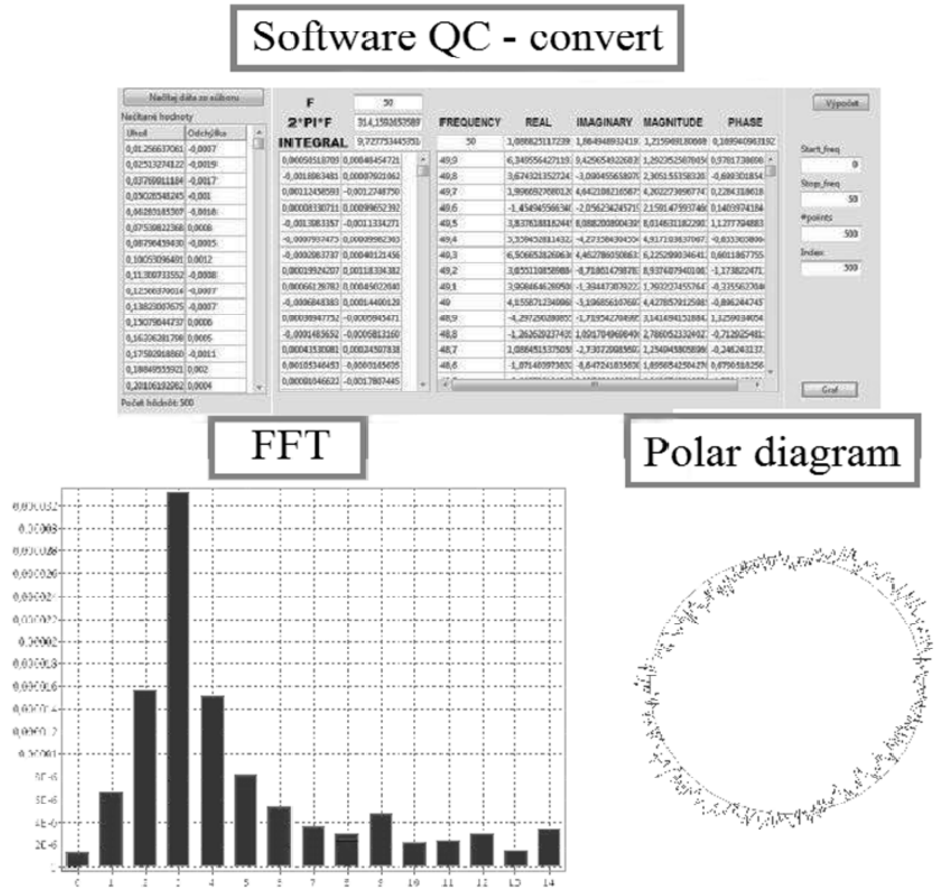

Fig.5. Software QC – convert

5. CONCLUSION

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 is too late to avoid scrap. It is better to check the machine before cutting any material. 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.

The development of various methods for measuring of machine tools is still a hot topic. There are a number 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 universal one alone. Progress in the development doesn’t necessarily ensure wide use in the practice in Slovak manufacturing companies.

The papers present a method to measure the geometric errors of CNC machine tools and diagnosis have been studied by using the Ballbar system (Ballbar QC 20 fy Renishaw) when we used the transformation of data structure (ballbar data) by using specialized software (QC - convert).

Output data from measuring device files are incompatible with our software so it was necessary to create a program that allows data processing and export it to readable form. For this purpose have been developed programs: ConverterTest and QC-converter intended for Ballbar devices.

At the beginning data obtained from ConverterTest by measurement were processed in Microsoft Excel, and compared using the graphical output. Measured roundness profile was decomposed into harmonic components using Fast Fourier Transform. Next correlations indexes between each measurement were calculated. It was necessary to verify the procedures for measured data processing and evaluation. Graphical results were compared through the SigmaRound software for Ballbar devices.

This program has been replaced by QC-converter. QC-converter performed all steps and replaces all the software. These programs are also applicable in other experiments performed by mentioned measuring devices. The geometric errors during circular interpolation motion were measured by detecting the relative distance between the spindle nose and the worktable using a connected Ballbar.

The geometric errors were plotted in polar coordinates. These errors were obtained for both CW and CCW motions and plotted in XY, YZ, and ZX axes. A comparison of the polar diagrams of the measured error motion with the out-of-roundness errors for the machined circular plate shows good agreement. Various error origins were then classified into several groups based on the motion error traces, and theoretical analyses were made to find out the trace pattern typical to each error origin.

The software has been developed to transformation of data structure and processing data to FFT analysis and we can compare it with the indirect method of measurement. By this method many NC machine tools have been diagnosed.

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