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BALLBAR QC10 MEASURING DEVICE – FAST EXPERIMENTAL CHECK OF MACHINE TOOLS ACCURACY

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ABSTRACT

Advanced technology and high productivity in production requires a high level accuracy of machine tools. The accuracy of machine tools is one of the most important characteristics for the production of demanding and complex part shapes. Checking and measuring accuracy of machine tools in the production cycle requires rapid diagnosis of potential inaccuracies in the machine tool. Ballbar QC10 measuring device is well known tool for fast and simple way of checking accuracy of machine tools. The device is utilizing circular interpolation of a machine tool in order to detect possible errors in machine movements.

This paper explains basic work principle of QC10 device through the process of controlling accuracy of a DMG Monoblock 60 high speed milling machine. The machine is placed in Laboratory for Metal Cutting and Machine Tools of the University of Zenica. Two measuring, circular tests were performed on the same position on machine table. The same center of circulation with the length of extension bar of 100 mm has been utilized but with time shifts of 6 years between the tests. The obtained results have been compared based on Renishaw Ballbar analysis.

Keywords: Ballbar system, CNC-machine tool, geometric accuracy.

1. INTRODUCTION

The geometric accuracy of CNC machine tools is a term that replaces a set of parameters that causing deviations from the ideal geometric shape of machined parts [1]. The main principles of measurement and monitoring of geometric accuracy is defined by corresponding standards. The set of ISO 230 standard defines how and in what way are carried out check of machine tools. From the set of ISO 230 standards, two standards are related to the above mentioned experiment [1,2,3,4,5]:

- ISO 230-1: Geometric accuracy of machines that work unladed or working in the finish treatment,
- ISO 230-4: circular test for numerically controlled machines.

The results of measurement and monitoring of dimensional and geometric errors of CNC machine tools dictates the necessary dynamics of machine maintenance. Of course, the well managed and appropriate maintenance will ultimately extend the life of exploitation of CNC machines [1]. Ballbar QC10 is measuring device produced in United Kingdom in 1991 by Renishaw. It is used for quick measuring and monitoring characteristics of CNC machine tools. Device works on the principle of measuring axial elongation of extension bar during machine circular interpolation. Main part of this device is LVDT (Linear Variable Differential Transformer) sensor shown on Figure 1b. Magnetic cup is attached on worktable and center cup is attached on main spindle of machine tool at the beginning of test, shown in Figure 1. Device works on the principle of moving steel balls that are placed on the end of the extension bar. Through an RS 232 port (COM), the LVDT sensor is connected with computer and suitable software, which detect axial movements of one steel ball relative to the other one. According to the limits of each machine and the different types of machines, various tests can be made: circular (360°), half-circular (180°) or one quarter of a circle test (90°) in XY, XZ or YZ planes. The basic radius of the Ballbar system is 100 mm, but it can be extended with additional bars to 150, 300 or 600 mm.

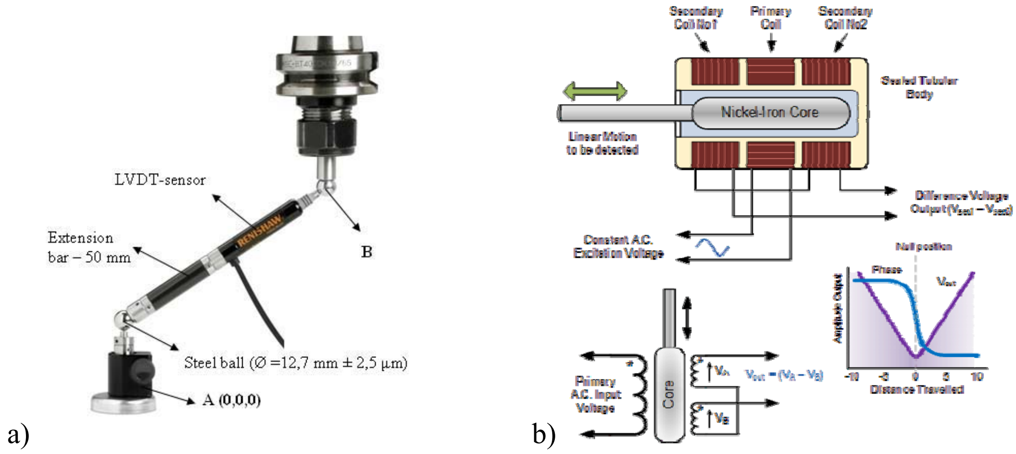

Figure 1. - (a) Ballbar QC 10 setting up, (b) LVDT (Linear Variable Differential Transformer).

During the test the computer shows and writes errors, which is the difference between the actual path of the spindle against the ideal path written in the NC program. Temperature calibration of the Ballbar device is done by means of the Zerodur plate. The test results might be presented and evaluated in graphical and tabular modes, and are in compliance with the ISO 230-4, ANSI B5.54 and JIS B6194 standards. The results can be classified with the "Help" program into 20 possible sources of errors..

2. EXPERIMENTAL SETUP

Experimental tests were carried at the Laboratory for Metal Cutting and Machine Tools (Faculty of Mechanical Engineering, University of Zenica). The tests were carried out on CNC machine tool DMU Monoblock-60. The CNC program is generated by Ballbar program generator, figure 3. First measurement had been done in 2009 and saved in machine database. The calibrated extension bar of 100 mm, XY plane and federate of 1000 mm/min has been selected for this test. The results of the test are shown in figure 3.

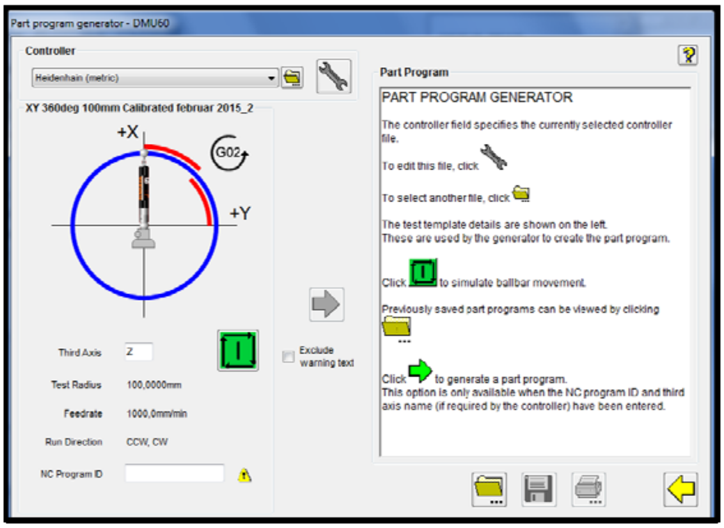

Figure 2. Ballbar test program generator

The same test, with same bar length, with approximately same position on worktable, in same XY plane and with identical CNC program has been repeated in February 2015. The results of this test are given in figure 4.

Obtained results were processed based on Renishaw Ballbar diagnostic tool. This diagnostic enable percentile sorting of the errors according to their significance and based on interpretation of the standard error plots. The results reveal that the main portion of the measured inaccuracy is devoted to *Scale mismatching error*.

3. RESULTS AND DISCUSSION

Obtained results for the both of the test have been shown on figure 3. and figure 4. From the presented results is obvious that the main percentage of the total machine error is due to scaling mismatch error. This type of machine error occurs when machine axes (X and Y in this case) either over traveling or under traveling relative to the other. Possible causes are: linear error compensation parameter might be set incorrectly, or the axis tape scale may be either over-tensioned or under tensioned, or the axis ballscrew may be faulty or overheating causing a ballscrew pitch error. The machine may be subject to an angular error, causing the X or Y axis to pitch out of the test plane as it moves.This is because the axis guideways are not straight or are not sufficiently rigid.

In 2009 this error takes 36% of total error, while in 2015 its contribution to total error was estimated on 33 %. Yet, decreasing of the percentile contribution does not mean that absolute value of the error in 2015 is less than in 2009. On the contrary, the error is increased from 10.9 μm in 2009 to 13.6 μm in 2015. Decreasing in percentile contribution of this type of error has been followed with increasing contribution of other type of mistakes, primarily the squareness.

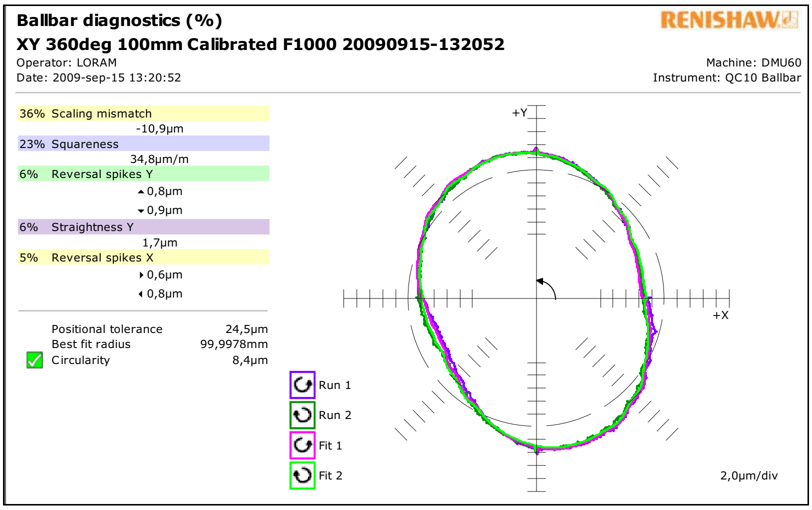

Figure 3 – Results of the test done in 2009

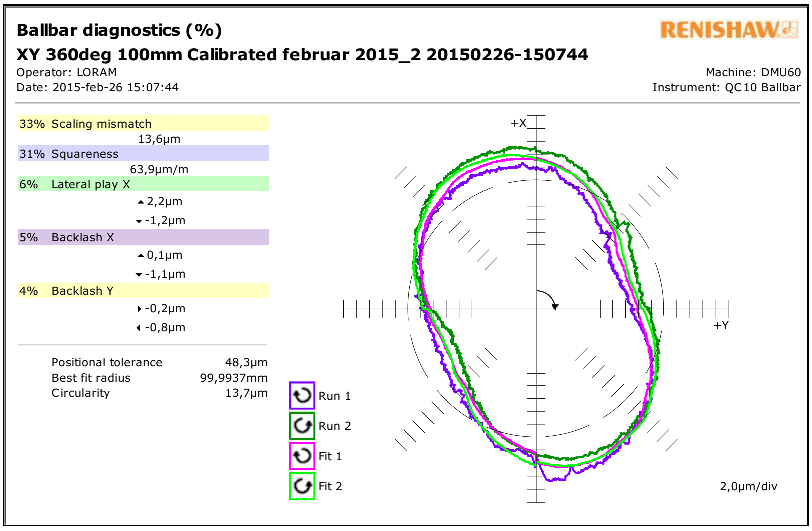

Figure 4. – Results of the test done in 2015

The squareness error is detected when X and Y axes of the machine are not at 90° to one another at the position on the machine where the test is being performed. The axes may be bent locally or there may be an overall axis misalignment in the machine. In both of the analyzed cases the squareness is the second most important type of error. In 2009, the squareness percentile contribution is 23% of total error. Its estimated values was 34,8 µm/m. In 2015, the same error contributes with 31% of the total error. But comparing the absolute values this error in 2015 is almost doubled with values of 63,9 µm/m. These results indicate that the machine guideways may be worn slightly during the time causing a certain amount of play in the axes when they move. The effect of a squareness error is that machined faces cut by the machine will not be ideally squared.

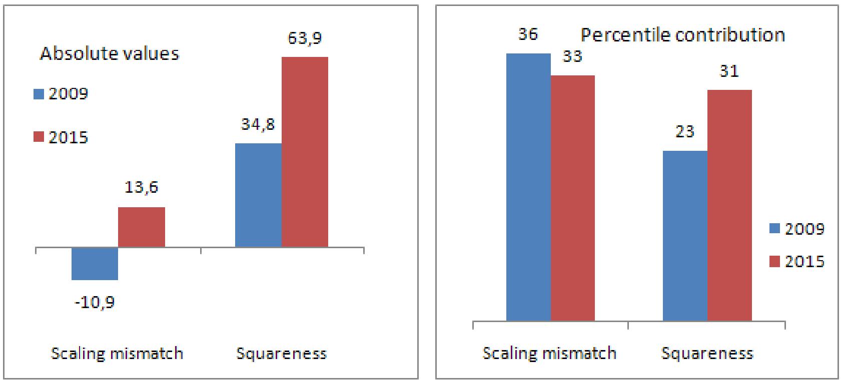

Figure 5. Diagrams of main errors distribution

In both analyzed cases described two type of the errors contribute about 2/3 of total machine error. The rest of the accuracy deterioration is caused by other types of errors like: lateral play, backlash, straightness, reversal spikes, servo mismatch, cyclic error etc.

In 2009 the errors are reversal spikes Y, straightness Y and reversal spikes X. None of these are essentially related to wearing process – worn guideways etc.

In 2015 the rest of the errors are: lateral play X, backlash X and backlash Y. Unlike to 2009, the errors in 2015 are actual consequence of the wearing process. For example, the main cause of lateral play is play or slop in machine guideways. This allows the axes of the machine to move at right angles to their guideways as the axis reverses. This should be contrasted with a backlash step, which is also caused by play, but in line with the axis.As seen on a Ballbar circular test, backlash is a radial error, whereas lateral play is a tangential error.

4. CONCLUSION

Appropriate maintenance of the machine tools required regular and periodical control of the machine tool. The best way of the controlling machine tool is to do it as fast as possible and possibly without unnecessary dismantling of machine components. This paper shows an example of using Renishaw Ballbar QC10 in detection of machine errors and estimation of its accuracy levels. Based on the presented results there are strong indication that the main source of the inaccuracy on analyzed machine tool is angular error or positive squareness error. X and Y axes are not ideally squared and that might be the cause of the both significant mistakes. This finding should be a trigger for detailed machine inspection – for example by using Renishaw ML10 interferometer for detecting exact value of angular error. In case that the detected error is outside of acceptable limits, maintenance service will be focused on corrective measures on real source of the error.

5. REFERENCES

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