ACCURACY MONITORING AND CALIBRATION
OF CNC MACHINES

Ivan Kuric¹, Ivan Ďurica², Miroslav Maduda³

¹,²,³ Department of Automation and Production Systems, Faculty of Mechanical Engineering, University of Žilina, Universitna 1, 010 26 Žilina, Slovakia, ivan.kuric@fstroj.utc.sk

Abstract: This paper deals with machining accuracy and accuracy of manufacturing machines and the possibility of regular diagnostic of machining centres in order to increase the productivity and quality of machining process.

KEYWORDS: accuracy, diagnostics, calibration, measurement, CNC machines

Introduction
The demands of modern industry to meet ever-tighter tolerances and to comply with international quality standards, mean that the performance of manufacturing machinery has never been more important. Process control and improvement is the key to raising quality and productivity, so increasing company’s competitiveness. The quality of every component produced on a CNC machine is highly dependent on the machine’s performance. Problems with a machine inevitably result in inspection failures, scrapped components and unexpected down-time. All too frequently, quality and inspection procedures identify problems after components have been produced. However, this is often too late to rectify any of the incurred scrap and down-time costs. For this reason, it is essential that machine performance is checked before component manufacture.

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. Workpiece dimensional and finish defects may result from bad tooing, worn spindles or workpiece clamping, but the major causes of defects can usually be attributed to positioning errors in the machine tool itself, the result of geometric, dynamic and play errors within the machine. To meet this demand, Renishaw produces measurement systems accepted worldwide as the industry standard to assess, monitor and improve machine performance. Machine productivity is increased, downtime reduced and scrap minimised. These systems combine the best available mechanical, electronic and optical technologies and have been designed for easy use, flexibility and portability. Systems normally reserved for
research laboratories and standards rooms can now be used directly on the shop floor. This systems provides a quick, powerful and accurate check on machine performance and is easy to use, saving time, money and waste.

In metrology, motion control, machine calibration, dental CAD/CAM and spectroscopy, measurement system innovations enhance precision, efficiency and quality. New measurement systems assess, monitor and improve the static and dynamic performance of machine tools, co-ordinate measuring machines (CMMs) and other position-critical motion systems.

2. Monitoring and diagnostics of CNC machines with QC 10 Ballbar

Renishaw's QC10 ballbar is a linear displacement sensor based tool that provides a simple, rapid check of a CNC machine tool's positioning performance to recognised internationals standards. QC10 ballbar system is a CNC machine tool diagnostic system. It consists of a calibrated sensor within a telescopic ball-ended bar, plus a unique mounting and centration system. It is not to be confused with the fixed length ballbars used for CMM (coordinate measuring machine) calibration. A ballbar test involves asking the machine to scribe a circular arc or circle. Small deviations in the radius of this movement are measured by a transducer in the ballbar and captured by the software. From the data supplied (via a PC interface) the systems software automatically detects and diagnoses a range of machine geometry, and motion errors. Recognised in many international standards for machine tool performance testing, the system is widely used by machine tool end users and OEMs and is considered vital equipment by many calibration service companies.

Fig.1: QC10 ballbar

Fig.2: Measurement with the QC10 ballbar
The ballbar accurately measures any deviations in the circle radius during the test. The shape of the ballbar plot indicates the major sources of machine error. Powerful software gives automatic analysis and diagnosis of specific machine error characteristics. Each error is ranked according to its significance to overall machine accuracy. Overall machine accuracy is graded with a value for circularity and positional tolerance.

The Renishaw QC10 Ballbar and its software are used to measure geometric errors present in a CNC machine tool and detect inaccuracies induced by its controller and servo drive systems. Errors are measured by instructing the machine tool to 'Perform a Test' which will instruct it to scribe a circular arc or circle. Small deviations in the radius of this movement are measured by a transducer and captured by the software. The resultant data is then plotted on the screen, to reveal how well the machine performed the test.

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. Test times will vary with test radius and machine feed rate but typically will be 10-15 minutes.

Fig.3: Renishaw QC10 ballbar test work and Renishaw QC10 ballbar software
The QC10 ballbar is an extremely versatile tool designed to be used on a large variety of machines. The standard system can be used to test 3-axis CNC machines such as horizontal and vertical machining centres. With the addition of other accessories detailed below, the QC10 ballbar can also be used to test a much wider range of machines. For 2-axis CNC applications, a special retractable centre mount, the VTL adaptor, is used. This enables typical 2-axis machines such as pick and place machines, laser cutting machines and vertical turning lathes etc. to benefit from QC10 ballbar diagnosis.

3. Calibration with laser interferometer system XL80

Renishaw's laser interferometer systems are used for comprehensive accuracy assessment of machine tools, co-ordinate measuring machines (CMMs) and other position-critical motion systems. They offer the ultimate in high accuracy, repeatable and traceable measurement, using externally mounted beam splitters. There are two Renishaw laser systems for performance assessment; the XL-80 (new for 2007) and the ML10, which has been in service since 1988.

Renishaw has been designing, manufacturing and supplying laser interferometer systems for over 20 years. Its ML10 laser system has become a standard for accuracy and reliability in use, enabling linear measurements to be made to an accuracy of ±0.7ppm. It has become the leading high accuracy, portable machine calibration and measurement system worldwide. In 2007 it has been joined by the XL-80 laser system with enhanced measurement performance (±0.5ppm, 50kHz, 4m/s) in a highly compact, portable and easy to use package, bringing the benefits of laser interferometry to an even wider audience.
The new XL-80 laser system offers greatly increased portability, system accuracy and improved dynamic measurement performance. It is quicker and easier to use, whilst retaining the benefits of a pure interferometry based system, a proven technology that has made Renishaw laser systems the preferred choice of companies worldwide. The basis of the new system is a compact laser head (XL-80) and an independent compensator system (XC-80). The XL-80 laser produces an extremely stable laser beam, with a wavelength that is traceable back to national and international standards. The XC-80 compensator is a key factor in XL system’s measurement accuracy. Featuring “intelligent sensors” that process the readings at source, the compensator very accurately measures air temperature, air pressure and relative humidity. The design of the XC-80 and sensors ensures extremely accurate readings over the full range of operating conditions, from units that are built to withstand the daily handling that most systems will receive.

The laser frequency stability is specified as ±0.05 ppm over 1 year and ±0.02 ppm over 1 hour. This excellent performance is achieved by dynamic thermal control of the laser tube length to within a few nanometres. Linear measurement accuracy is an assured ±0.5 ppm, over the whole environmental range i.e. from 0°C – 40°C and 650 mbar – 1150 mbar. Readings are taken at 50 kHz, with a maximum linear measurement speed of 4 m/s and a linear resolution of 1 nm; even at maximum speed.

The XC-80 compensator is a key factor in XL system’s measurement accuracy. Featuring “intelligent sensors” that process the readings at source, the compensator very accurately measures air temperature, air pressure and relative humidity. The design of the XC-80 and sensors ensures extremely accurate readings over the full range of operating conditions, from units that are built to withstand the daily handling that most systems will receive.
4. Conclusions

Renishaw’s QC10 ballbar offers the perfect solution. A quick 10 minute test is all that is required to assess the performance of machine. The quickest, easiest and most effective way to monitor machine tool condition. The ballbar kit provides a complete, powerful and portable solution.

Many inspection procedures take place after the component is produced. This is too late. To avoid scrap it is better to check the machine before cutting any metal. Pinpointing the specific machine faults enables efficient, targeted machine maintenance, minimising downtime. Plan predictive maintenance programs by tracking machine performance.

Renishaw’s probing systems cut almost all costly machine down-time and eliminate scrap components associated with manual inspection and setting. Renishaw’s probing systems are used by companies worldwide to increase productivity and improve part quality. They can be specified as standard equipment from most leading manufacturers.

The use of a specialised diagnostic tool - the Renishaw QC10 telescopic ballbar has gained widespread recognition as the best and most practical method for quickly checking machine positioning performance. The Renishaw QC10 ballbar is tried and tested. With such a simple test, its suitable for supervisor or operator use (options selectable) and the auto diagnosis software means getting useful information not data.

Note: The article was made under support project Nr. KEGA 3/5172/07

References