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MONITORING OF CNC MACHINE TOOL ACCURACY

Summary: 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. Therefore is also importance to evaluate the accuracy of machine tools and make prediction of possible inaccuracy. The paper deals with aspects of qualitative parameters of machine tools and their influencing on product quality. Several methods of measurement of accuracy of machine tools and monitoring methods will be presented.
Keywords: quality, methods of measurement, parameters of machine tools.

INTRODUCTION

Some CNC machine tools are more accurate and some are less accurate, just as some machines have large travels and some have small ones. This view is partially true. The first step in achieving machine tool accuracy is to ensure proper set up. Second is to provide feedback devices on the slides and spindle that will tell how well the machine is, or is not, operating.

However that machining center is also part of a system. The machine is set up a certain way and run a certain way. It exists within an environment in which the temperature, among other factors, is subject to change. And the machine components dynamically affect one another components and their influence on final accuracy are very complex task. That means all of these components influences contribute to the machine's accuracy, so all of them potentially have to be taken into account.

Quality is perhaps the oldest concept by which a product can be evaluated thus identifying or describes the level of customer satisfaction with the product. 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 such conditions, that it will be able to produce parts that meet the demanded accuracy. Very low tolerances or very high quality surface can cause unnecessary production costs, hence a high cost product. Positive is high reliability and long-time use. In contrast, products with low prices have a positive impact on enterprise competitiveness.

In terms of achieving higher precision and better performance, requirements are placed on high stiffness for the machine units. This requires the use of quality

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materials and advanced processing technologies. The economic effect in the rational use of automated systems is given primarily through greater productivity, quality and reliability in producing parts. This can of course ensure the company a competitive advantage.

MACHINE TOOL ACCURACY

Machine tool precision is characterized by the ability of the machine to produce parts of the required geometry and dimensions keeping the required tolerances and to achieve the desired roughness. Requirements for precision of the machine tools result from the required precision of components manufactured on the machine. Because on one machine are usually manufactured different surfaces of a component of different geometric shapes, it is necessary to respect the accuracy of fundamental dimension elements of machine, such as: flatness and straightness of guide surfaces, alignment clamping surfaces, parallelism of axes with guides, the perpendicular shaper required from the spindle axis with the clamping surface of the table, etc. Compliance with the required accuracy of manufacture and assembly of parts and machine nodes can achieve static precision of the machine tools. It is known as geometric accuracy. The geometric accuracy of the machine tool is the precision of shape and position of its individual parts and their mutual movements. It is necessary but not a sufficient condition for ensuring the required precision of the machine tool manufacturing. It depends on the accuracy of the relative shape of the path of the work-piece and tool, ultimately, the accuracy of the shape and surface relative position of the work-piece manufacturing on the machine tool. Initial acceptance conditions for the control of geometric accuracy of machine tools compiled in 1927, Professor on Technical University in Berlin - Charlottenburg dr. Georg Schlesinger. These conditions have been taken in the main features by all industrialized countries and appropriately adjusted for current conditions. These are the basis of ISO, DIN, EN, etc.

Precision machine tool is primarily determined by accuracy of the individual parts and its nodes. Because these parts are produced by conventional machining methods, their dimensions, shapes and relative positions are determined on the drawings by tolerances, which have to be in manufacturing and assembly process precisely observed.

Measuring the linear axis displacement is not enough. While all machine tool builders are trying to build the best possible machine, there are many variables that can be a source of potential errors. For example, the transport itself can cause problems. If the machines are installed at the customer, the dividing changes and assembly may also affect the geometry of the machine tool. Naturally, everyday wear during use causes the machine to losing accuracy. That is why the ISO standard specifies machine tools and forming machines calibration in half-year intervals.

INACCURACY OF MACHINING

In production of machined parts it is not practically possible to produce parts with full precision. The machined parts dimensions are always different from the nominal values mentioned in the design drawings. Relevant deviations are bound with many factors, from which the most important one would be the production process. Some finishing operations allows reaching the nominal dimension, coming very close to it, so the difference between the actual dimension and dimension mentioned in the drawing is very small.

Total inaccuracy of machining can arise from series of factors. Among them, these are the most significant:

- inaccuracies due to elastic deformation of technology system machine - tool - workpiece from the cutting forces and resistances,
- inaccuracies caused by thermal deformations of technological system,
- inaccuracies due to wear and tear of cutting tool,
- inaccuracies of machine sorting and of workpiece material composition,
- inaccuracies due to distortions in the workpiece by clamping forces,
- inaccuracies due to geometric and kinematic machine tool inaccuracies,
- inaccuracies due to geometric irregularities of the cutting tool,
- inaccuracies due to internal stresses in the workpiece material,
- inaccuracies due oscillation in the technological system,
- inaccuracies due to fluctuations of input size parameters of the workpiece and the material inhomogeneity.

From the list above it is possible to state, that the most important factor of machining accuracy is the machine tool and its accuracy.

TESTING MACHINE TOOL

Before a machine tool goes into operation, it's essential to check straightness, linear, and squareness. The two key instruments needed to do this are a ballbar QC20 and a laser XL 80 interferometer. Laser systems apply both static and dynamic tests. The static tests include basic measurements such as linear and squareness. The dynamic tests evaluate positioning error. There are laser alignment systems and laser interferometers. The alignment system checks only static conditions. A laser shines a beam on a calibrated target and where the beam strikes the target determines error. The interferometer does both static and dynamic tests. In either operation, a laser beam is bounced off a reflector, and the system electronics compare the outgoing and incoming beam to determine such things as distance and rotation. The ballbar QC20 is an instrument that evaluates the volumetric accuracy of a machine tool. One end is attached by a magnetic coupling to a point on the machine tool worktable, the other end to the spindle. The machine is programmed to follow a circular path. As the spindle moves, any variation from a constant radius forces the ballbar QC20 to extend or retract. Any deviation from the programmed radius is measured via the extensions and retractions. The resulting signal is transmitted to a computer or other recording device. Earlier ballbar QC20 systems required the user to interpret the plot. This task is now becoming easier. Readings from these tests may require anything from a slight adjustment to a major rework of some machine tool element. In some cases, the errors can be factored out by allowing for them in the programming.

CNC machine TOOLS diagnostics

Machine tools condition monitoring is main prerequisite for maintaining production quality as well as necessary requirement in quality control systems according to ISO 9001 standards. Observe machinery preventive geometry according to production wasters is obsolete. Current tendency is to foresee - predict machinery condition and ensure production quality accordingly. Following this it is possible to ensure satisfactory production even on machinery with worse characteristics.

This provides monitoring by decreasing machinery service costs and at the same time maintains high production quality by means of NC and CNC machinery diagnostics. This is applied throughout our customer base especially companies working in machinery industry.

Registry is being compiled from performed measurements which gives us continual view of machinery development. Which particular machine tool is capable of fulfilling requirements for manufacturing accuracy can be assessed with use of this registry. With this classification and its periodical repeating is possible to decrease scrap costs coming from allocating product to particular machine. By observing development trend of manufacture accuracy is possible to schedule machinery maintenance/repair before major malfunction occurs. This will significantly decrease costs caused by machinery breakdowns. Customer gets overview of his machine pool accuracy including machinery accuracy protocols according to ISO 9001 standards.

Technical diagnostics can be divided from the viewpoint of complex solution to the following:

- discovery of rising malfunction – detection,
- assigning of defective unit or node – localization,
- prognosis of remaining operating life – prediction.

The technical diagnostics has the following aspects:

- very high assurance and reliability with perspective on prolongation of maintenance cycles and reduction of further damage,
- objective technical condition must be determined without dismounting and operation discontinuation,
- evaluation must be done based on reliability of whole machine system.

Diagnostics from the viewpoint of machinery is known as:
- preassembly diagnostics,
- diagnostics after final assembly - during debugging and final inspection,
- operating time diagnostics - service, inspectional or monitoring.

It is possible to meet with the following types of diagnostics:
- vibrodiagnostics,
- tribodiagnostics,
- thermography,
- acoustics,
- geometric parameters.

DIAGNOSTICS USING LASER XL80 AND BALLBAR QC20

Laser XL80

The Renishaw XL laser measurement system enables the complete calibration of machine tools and other position sensitive systems, allowing the measurement of a wide range of geometric and dynamic machine characteristics and has many applications in scientific and engineering research. This is so far the most accurate machinery diagnostics.

Machine geometry can be catched up with this measurement (perpendicularity, straightness, flatness, cross clearance, backlash, gauge adjustment). It depends all on the used optics.

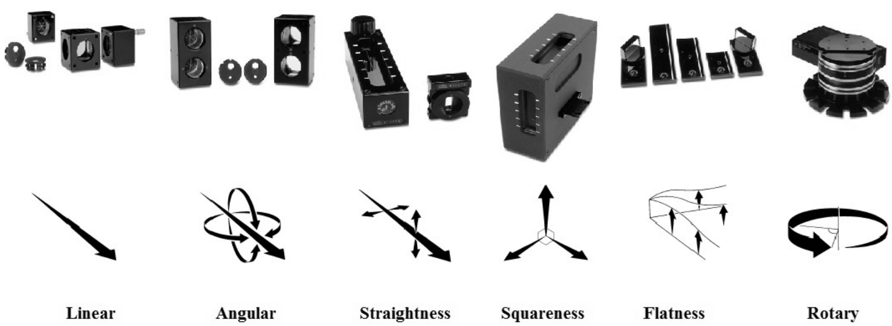

Fig. 1. Laser optics XL80

Measuring is always carried out on unloaded machine. Measuring period depend on machine type and number of measured planes.

Protocol is compiled from actual measurement and contains:
- graphical representation of error behaviour along measured axis length,
- table of measured data,
- machine`s condition evaluation,
- recommendations on found faults.

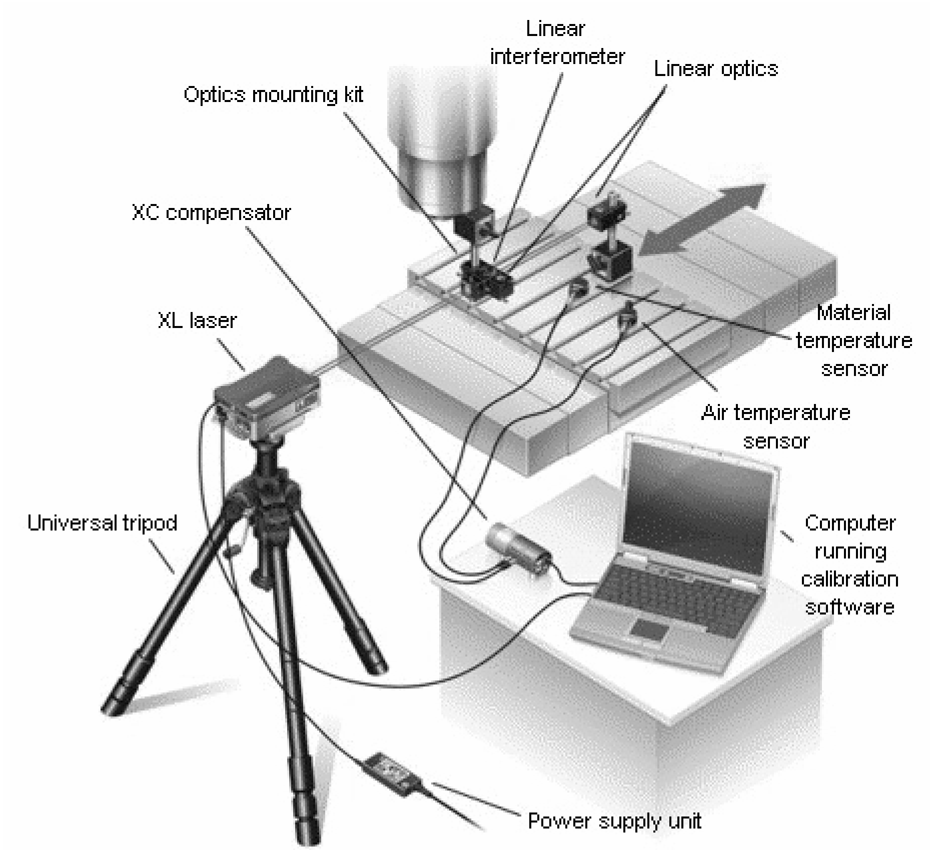

Fig. 2. Measurement using Laser interferometer

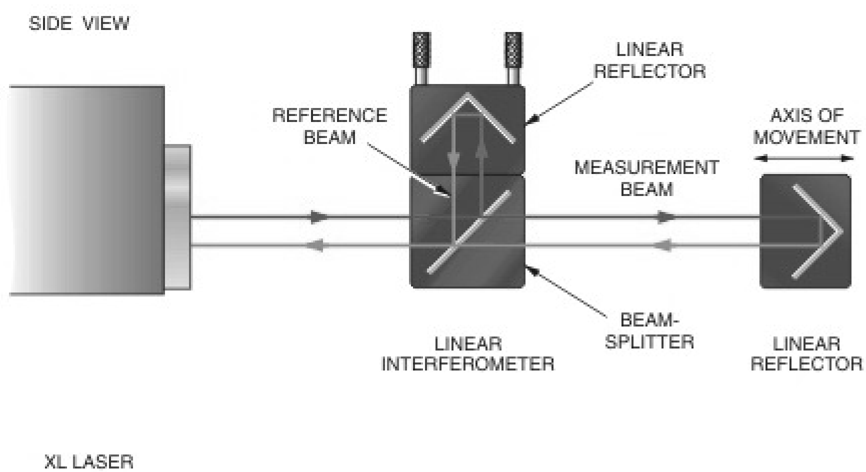

Fig. 3. Principle of measurement

Measurement of gauge adjustment including corrections: the beam from the XL Laser enters the linear interferometer, where it is split into two beams. One beam (known as the reference beam) is directed to the reflector attached to the beam-splitter, while the second beam (the measurement beam) passes through the beam-splitter to the second reflector. Both beams are then reflected back to the beam-splitter where they are re-combined and directed back to the laser head where a detector within the head monitors the interference between the two beams.

Captured data can be analysed in accordance with a number of international standards (fig. 4). Individual international standards describe the method required for collecting and analysing data, with various factors, such as the number of target positions required, varying depending on the standard used and machine type being tested. When carrying out any analysis of captured data, ensure the analysis you select is suitable for the type of machine you are testing and your test requirements. Data capture is carried out by moving the machine to a number of different positions (or 'targets') along the axis under test and measuring the machine's error. You can write a part program to drive the machine from one target position to the next, pausing for a few seconds at each target position. Measurements are taken during each pause. When choosing the target positions for a calibration of a machine's axis, the target positions should usually span the working zone of the axis.

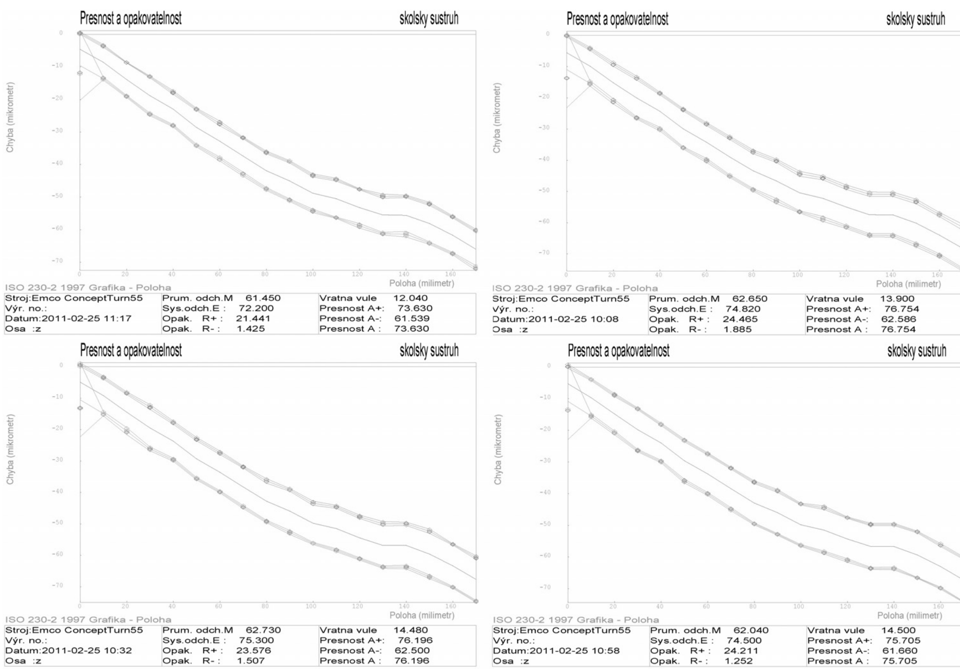

Fig. 4. Evaluation of the result at various velocities machining

Ballbar QC20

The Renishaw Ballbar QC20 and 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. 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 you will use during your test with a QC20-W ballbar are shown in the figure 5.

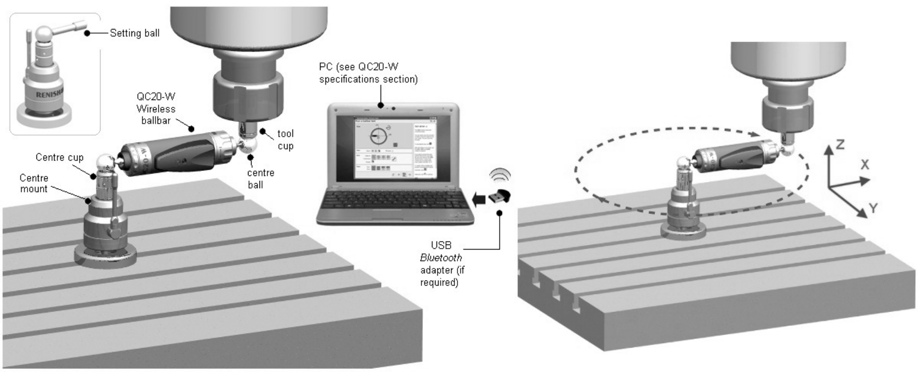

Fig. 5. The items of hardware Ballbar QC20

The QC20-W allows machine calibrations to be conducted in the XY, ZX and YZ planes without having to setup and re-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 diagnosed.

The Ballbar 20 software can automatically analyse 360º and 220º ballbar plots and diagnose machine errors (fig. 6).

Plot errors can be caused by machine errors and test errors. Machine errors are errors or faults in the machine under test. Test errors or are errors or faults in either the ballbar or the way the test was carried out.

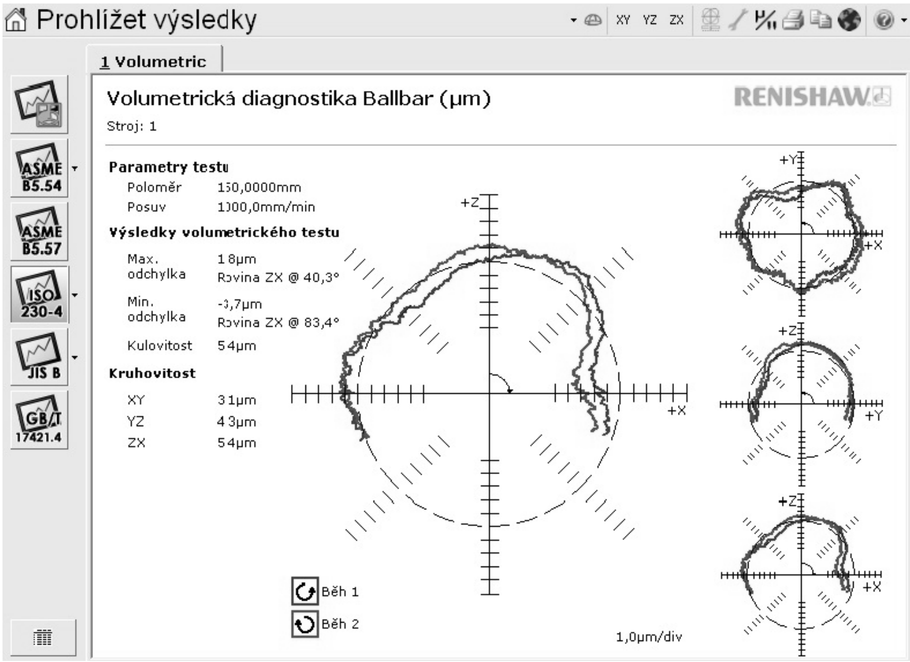

Fig. 6. Background software ballbar

CONCLUSION

For each methods of machine tool diagnose must follow certain procedures – measurement a methodology and evaluation. Proper technical diagnosis is provided high security and reliability with a view to extended maintenance cycles and limiting consequential damages. Objective technical status should be determined without dismantling and disruption. Determination of inaccuracy of CNC machine tool is very complex task. There is a lot of confluences in the machine tool as all components and nods have some inaccuracy.

The quality of every component produced on a CNC machine is highly dependent on the machine's performance. 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. 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.

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MONITOROWANIE DOKŁADNOŚCI OBRABIAREK CNC

Streszczenie

Występuje wyraźny związek między parametrami jakościowymi obrabiarek i parametrów jakościowymi produktów (tolerancja, chropowatość, itp.). W związku z tym bardzo ważne jest, aby trzymać stabilność wskaźników jakościowych produktów, będącej kluczem do jakości produkcji. Wynika z tego, że równie ważna jest ocena dokładności obrabiarek i narzędzi oraz możliwość prognozowania możliwości wystąpienia niedokładności. W artykule omówiono aspekty parametrów jakościowych obrabiarek i ich wpływ na jakość produktów, a także przedstawiono kilka metod pomiaru dokładności obrabiarek oraz metod monitorowania.

Słowa kluczowe: jakość, metody pomiaru, parametry obrabiarek.